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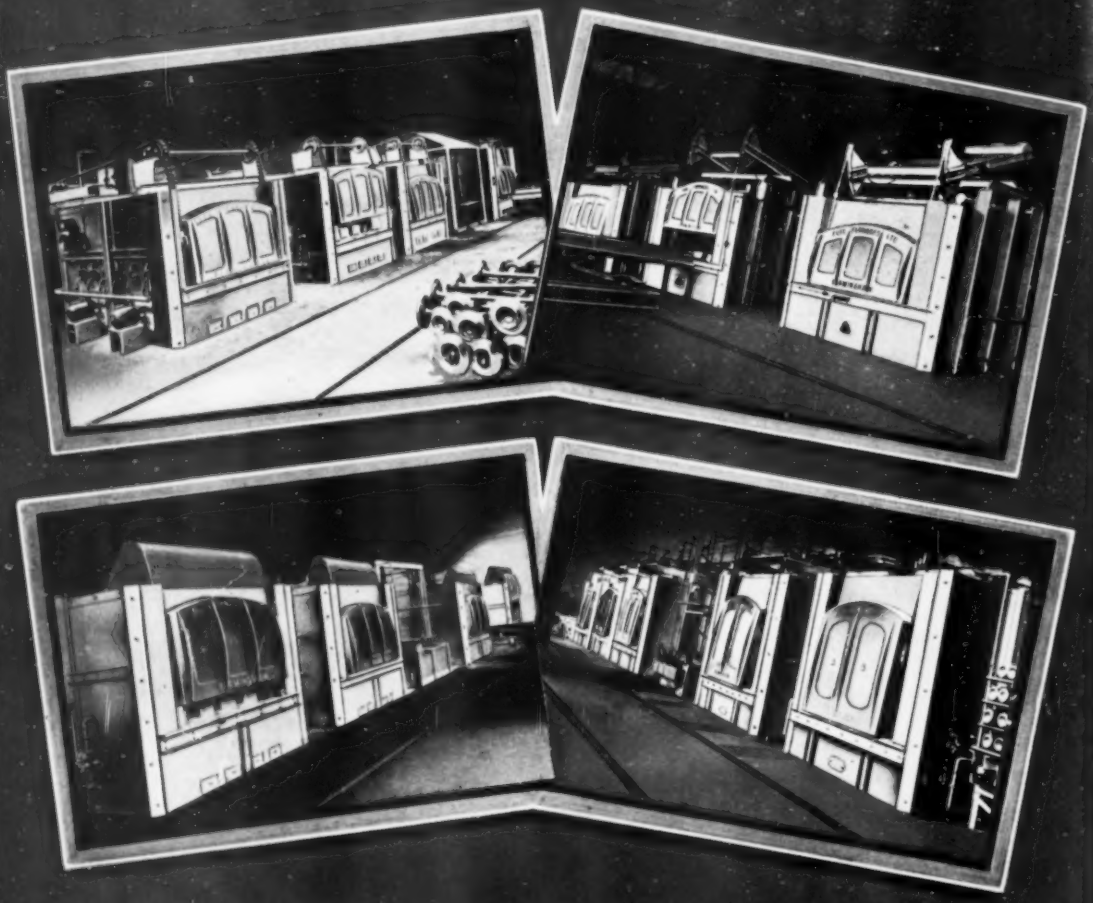

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR APRIL, 1955 Vol. 51 No. 306

PUBLISHED MONTHLY BY
The Kennedy Press, Ltd.,
31, King Street West,
Manchester, 3.
Telephone: BLAckfriars 2084

London Office:
50, Temple Chambers,
Temple Avenue, E.C.4.
CENtral 8914

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CONTRIBUTIONS

Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

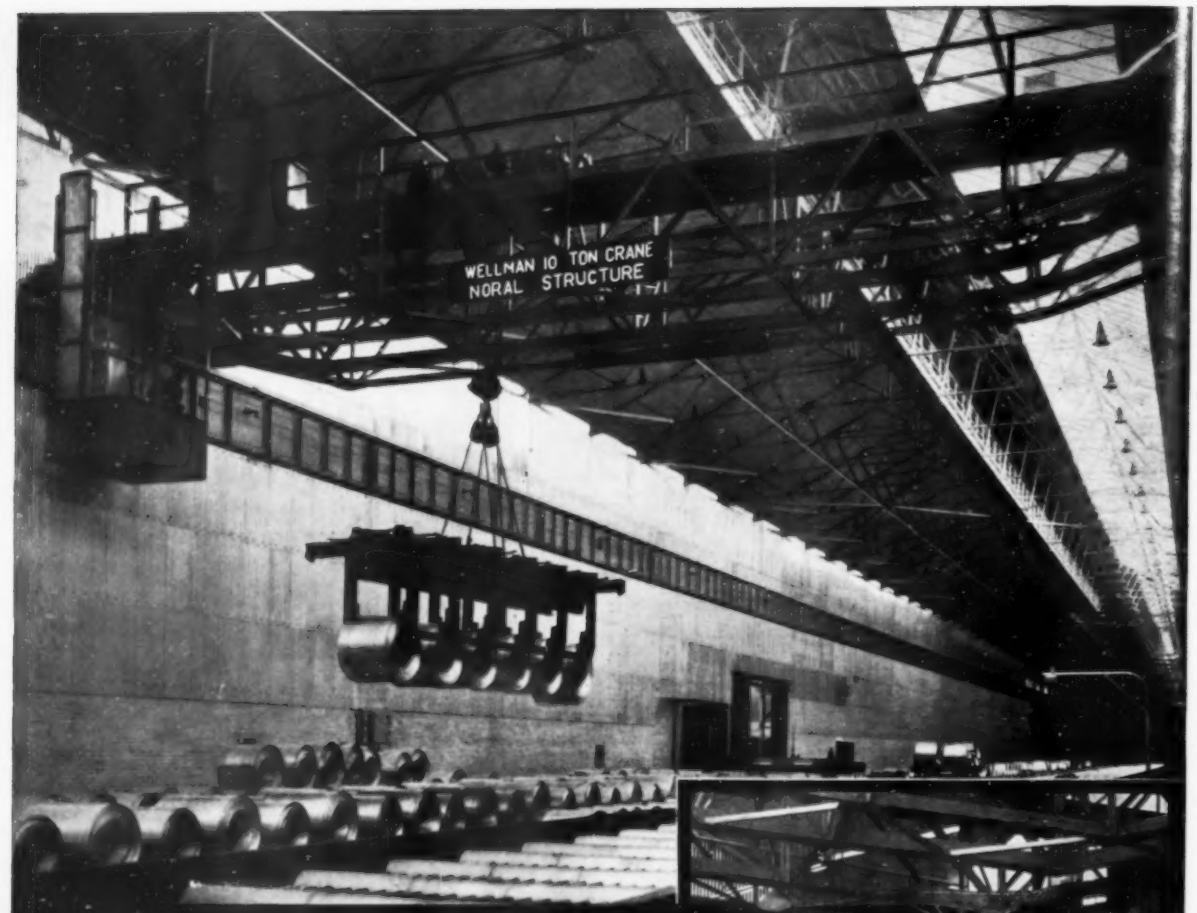
SUBSCRIPTIONS

Subscription Rates throughout the World—24/- per annum, Post free.

ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

The articles in this Journal are indexed in THE INDUSTRIAL ARTS INDEX



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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

APRIL, 1955 Vol. LI. No. 306

The Automatic Factory

IT is inevitable that many of the factories of the future will be concerned with new developments, new techniques and new equipment, which will advance us very considerably in the direction of the automatic factory, as Sir Walter Puckey, President of the Institution of Production Engineers, pointed out recently when discussing the Conference on "The Automatic Factory—What Does it Mean?", which is to be held at Margate in June.

There is nothing fundamentally new in the concept of the automatic factory. It is a logical outcome of development which has been taking place since man discovered that by the use of the lever and the wheel he could improve on the results he achieved with his unaided muscular effort. Later, the development of water power and, more particularly, the steam engine led to the Industrial Revolution and the introduction of factory working in place of domestic industry. Since that time, machine development has continued at an increasing tempo, and the worker has been given more and more "power to his elbow". Just as Watts' steam engine may be considered to be the "father" of industrialisation, so too may the automatic factory be regarded as an outcome of developments in the field of electronic engineering.

The vision conjured up in many people's minds by the term automatic factory is still far from achievement, but very real progress has been made, as may be judged from the following examples taken from *PERA Bulletin*. A 60-ft. automatic transfer plant in this country has replaced a line of 18 standard machines on which 13 operators produced 750 motor-car gear boxes per week: only four men are now required to produce 1,600 gear boxes in the same time. Automation reduced direct labour for coil spring manufacture in one firm from 248 to 38, and a 6,000 sq. ft. production line on which 22 men manufactured thermostats has been replaced by a unit occupying 10 sq. ft. and operated by one man. A completely automatic factory for the production of engine pistons in the U.S.S.R. is claimed to have a production capacity of 3,500 piston heads per day, and "only five men per shift are needed to run the factory". All operations, including casting, and the final inspection and packaging of the pistons, are carried out automatically.

Production with full automation is normally only economically practicable if the heavy capital and development costs are spread over large quantities of components, but it may be possible to adopt some degree of automation, even in small quantity production. In such cases, more flexible methods, such as machines controlled by magnetic or punched tapes—which can readily be changed to produce different components may be adopted. Automation has been developed to a considerable extent in the U.S.A. and Russia, and to some extent in France and Germany, as well as in Britain. Extensive adoption of these techniques abroad could have serious repercussions on our export trade, which is vital to the maintenance of the present standard of living. It is thus essential, that we in this country should keep abreast of developments in this field. The decision of the Council of the Institution of Production Engineers to organise the Margate Conference referred to earlier—the first on the subject in this country and, it is believed, in the world—is, therefore, to be warmly welcomed, offering as it does an opportunity for ventilating some of the problems associated with automation.

Not all these problems are technical, and the Institution hopes to devote as much time at the Conference to economic and sociological questions as to technical ones. One of the problems to be tackled will be that of convincing the worker that greater automation, far from displacing people, will give greater opportunities to all, by new industries arising to make new products; new ways of reducing drudgery; better safety measures; and greater leisure created by bringing more machines into the service of man. The days of the Luddites are gone, but with figures such as those given in the examples of automation quoted above, one cannot but expect the worker to wonder whether such developments are not jeopardising his future.

On the technical side, a committee has been set up by PERA (the Production Engineering Research Association of Great Britain) to consider aspects of research which would be likely to help industry in the further development and application of automation. A high standard of mechanical reliability is essential to prevent costly interruption in automatic production lines, and the development of devices to indicate potential sources of failure will yield dividends. Similarly, tools must be changed rapidly: there is considerable interest in special toolholders which can readily be replaced by other holders with accurately pre-positioned tools. Other problems associated with the practical application of automation include the development of versatile mechanical handling devices, the arrangement and construction of machine controls for automatic operation, and the development of mechanisms for the production of complex components on one machine. Nor is the production engineer the only one involved. More than ever before must the designer pay attention to the way in which a component is to be made, as well as to its function, and considerable preliminary investigation of production methods may be necessary before equipment is installed.

Automation is likely to revolutionise our manufacturing methods as did the steam engine before it, and if we are to hold our own in world markets, we must as Sir Walter Puckey said, "be willing to accept the great changes that technology will make possible in the next few decades, and to resolve that the many mistakes which overshadowed the triumphs of the first Industrial Revolution shall not mar the realisation of the second".

Meeting Diary

6th April

Institute of Metal Finishing (Scottish Branch). Paper by E. A. OLLARD (Subject to be announced). Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow. 7 p.m.

7th April

Institute of Welding (North Eastern —Tees Side—Branch). Annual General Meeting and films. Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 7.30 p.m.

11th April

Institution of Engineering Inspection (East of Scotland Branch). "Arc Welding and Examination of Welds" (illustrated), by R. D. BERRY Royal British Hotel, Dundee. 7.30 p.m.

Institute of Fuel (North-Eastern Section). Lecture by the President, DR. W. IDRIS JONES, C.B.E. Title to be announced. Chemistry Lecture Theatre, King's College, Newcastle upon Tyne. 6.30 p.m.

12th April

Institute of Welding (North London Branch, Slough Section). Annual General Meeting, followed by Technical Session. Community Centre, Farnham Road, Slough. 7.30 p.m.

Institution of Production Engineers (Birmingham Graduate Section). "Efficient Production Methods Applied to Iron Founding," by G. W. NICHOLLS. James Watt Memorial Institute, Great Charles Street, Birmingham, 3. 7 p.m.

14th April

Institute of Fuel. Paper by the staff of B.C.U.R.A. Institution of Civil Engineers, Great George Street, London, S.W.1. 5.30 p.m.

Institute of Metals (London Local Section). Annual General Meeting followed by a Discussion on "Recent Developments in Special Machining Techniques." 4, Grosvenor Gardens, London, S.W.1. 6 p.m.

Institute of Welding (North Eastern—Tyneside—Branch). "The Economic Proportion of Welding in Shipbuilding," by W. R. MELLANBY. Mining Institute, Neville Hall, Newcastle upon Tyne. 7 p.m.

Institute of Welding (Portsmouth Branch). Annual General Meeting and Technical Films. Royal Beach Hotel, Southsea. 7 p.m.

Institute of Welding (South London Branch). Annual General Meeting, followed by Debate—"This Meeting considers that all Welders should be Certified." 2, Savoy Hill, London, W.C.2. 6.30 p.m.

Liverpool Metallurgical Society. Annual General Meeting followed by "Materials Resistant to Creep at High Temperatures," by A. W. FRANKLIN. Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool. 7 p.m.

15th April

Institute of Welding (Sheffield Branch). Annual General Meeting and Film Show. Grand Hotel, Sheffield. 7.15 p.m.

Institution of Mechanical Engineers. "Surface Examination by Reflection Electron Microscopy," by DR. J. S. HALLIDAY. 1, Birdcage Walk, Westminster, London, S.W.1. 5.30 p.m.

West of Scotland Iron and Steel Institute. "Recent Developments in Refractories—Their Effect on Steelmaking," by H. PARNHAM. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

16th April

Institution of Production Engineers (Peterborough Section). Film—"Precise Measurement for Engineers," introduced by S. P. POOLE. Campbell Hotel, Bridge Street, Peterborough. 7.30 p.m.

18th April

East Midlands Metallurgical Society. Annual General Meeting, followed by "Centrifugal Casting," by E. MORGAN. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7.30 p.m.

Institute of Metal Finishing (London Branch). (Joint Meeting with the Organic Finishing Group). "Electrostatic Painting Processes," by R. TILNEY. The paper will be followed by a film dealing with Electrostatic Spraying. Northampton Polytechnic, St. John Street, London, E.C.1. 6.15 p.m.

Institute of Metals (Sheffield Local Section). Films (details to be announced). University Buildings, St. George's Square, Sheffield. 7.30 p.m.

Sheffield Society of Engineers and Metallurgists. Film Night. University Building, St. George's Square, Sheffield. 7.30 p.m.

19th April

Institution of Production Engineers (Luton Section). "Cold Forming of Light Alloys," by D. A. BARLOW. The Small Assembly Room, Town Hall, Luton. 7.15 p.m.

20th April

Institute of Fuel (Midland Section). Visit to Laboratories of Chemical Engineering Department, Birmingham University, to be followed by "Training of the Chemical Engineer in Fuel Technology," by PROF. F. H. GARNER and DR. R. LONG. (Time to be announced.)

Institute of Fuel (North-Western Section). Annual General Meeting—Visit of the President, DR. W. IDRIS JONES, C.B.E. Engineers' Club, Albert Square, Manchester. 2.15 p.m.

Institute of Welding (West of Scotland Branch). Annual General Meeting and Film Show. Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2. 7 p.m.

Institution of Production Engineers (Birmingham Section). "The Development of Special Machines with particular reference to Unit Construction," by T. W. ELKINGTON. James Watt Memorial Institute, Great Charles Street, Birmingham, 3. 7 p.m.

Institution of Production Engineers (Wolverhampton Graduate Section). "Recent Developments in Metal Machining," by K. J. B. WOLFE. Wolverhampton & Staffordshire Technical College, Wulfruna Street, Wolverhampton. 7.30 p.m.

North East Metallurgical Society. "Research and Development in the Continuous Casting of Steel," by J. SAVAGE. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

Society of Instrument Technology (Newcastle Section). "Electronic Computers," by A. ST. JOHNSTON. Stephenson Building, King's College, Newcastle upon Tyne. 7 p.m.

21st April

Institute of Fuel (East Midland Section). Annual General Meeting, followed by "Nuclear Power," by PROF. J. ROTBLAT. Gas Showrooms, Nottingham. 6.15 p.m.

Institute of Welding (North London Branch). Annual General Meeting, followed by Technical Session. B.W.R.A., 29, Park Crescent, London, W.1. 7.30 p.m.

Institution of Production Engineers (London Section). "Electronics in Modern Industry," by R. H. BOOTH. Royal Empire Society, Northumberland Avenue (Craven St. Entrance), London, W.C.2. 7 p.m.

Royal Institute of Chemistry, Chemical Society, Institute of Petroleum and Society of Chemical Industry. Annual Symposium (full-day) "Organo-Metallic Compounds." Speakers: PROF. K. ZIEGLER, DR. E. A. BRAUDE, PROF. G. E. COATES, DR. J. CHATT, DR. F. G. MANN, DR. M. C. WHITING. Chemistry Lecture Theatre, The University, Manchester. 10.30 a.m.

22nd April

Institute of Welding (Birmingham Branch). "High Frequency Heating," by K. A. ZANDSTRA. Birmingham and Midland Institute, Paradise Street, Birmingham, 1. 7.30 p.m.

25th April

Institution of Production Engineers (Manchester Graduate Section). "From Diamond to Spark Machining," by G. FEFER. Reynolds Hall, College of Technology, Sackville Street, Manchester. 6.45 p.m.

26th April

Society of Instrument Technology. "Magnetic Amplifiers as Industrial and Laboratory Aids," by R. J. RUSSELL-BATES. Manson House, Portland Place, London, W.1. 6.30 p.m. for 7 p.m.

27th April

Institution of Production Engineers (Shrewsbury Section). "Manufacture of Springs," by J. A. ROBERTS. Shrewsbury Technical College, Shrewsbury. 7.30 p.m.

Society of Chemical Industry Corrosion Group. Annual General Meeting followed by Chairman's Address. Chemical Society, Burlington House, Piccadilly, London, W.1. 6.30 p.m.

The Use of Creep-Resisting Steels in Steam Power Plants

By H. W. Kirkby, A.Met., F.I.M.

The Brown-Firth Research Laboratories, Sheffield

In several new British power stations at present under construction the steam turbines have been designed to operate at 1,050° F (566° C) steam temperature and 1,500 lb./sq. in. pressure, and the selection of steels for the main steam piping is perhaps, one of their most interesting features, as at 1050° F, consideration has to be given to the relative merits of ferritic and austenitic steels. In reviewing the influence of these and higher operating conditions on constructional materials, the author discusses steels for piping, turbine rotors, turbine blades and bolts.

SINCE World War II, much publicity has been given to the development of the gas turbine and the high temperature materials associated with it. The important changes taking place in connection with the land steam turbine, however, appear to have received scant attention. An interesting account of the development schemes applicable to Great Britain up to 1960 has been published by the British Electricity Authority in its last Annual Report,[1*] which also gives details of general progress made during the years 1953–54.

For the metallurgist, the outstanding feature of this report is the development of designs for larger boilers and turbines with higher steam conditions, primarily for improving thermal efficiency. The once-styled "standard" turbine of 60 MW. is now giving way to the 100–120 MW. set, and a 200 MW. set† has also been designed for installation within the next few years.

Improvements in thermal efficiency are of national importance, judging by the fact that it is estimated that during the last 6 years the increase in the average overall thermal efficiency from 20·87% to 23·40% has resulted in a saving of £34,000,000 and nearly 12 million tons of coal. All the new stations are in the higher efficiency class, three of the most modern each having a thermal efficiency of over 30%.

Various factors contribute to the improvements now being made in steam turbines, but it is largely the advances in steam temperatures and pressures which have a direct bearing on the application of creep-resisting steels, which is the subject of the present article.

Steels for Steam Pipes and Superheater Tubes

Carbon-Molybdenum and Chromium-Molybdenum Steels

Table I shows typical analyses and initial heat treatments of steels at present in use in this country for both pipes and tubes, and includes those steels which will operate under the more advanced steam conditions. Fig. 1 summarises their respective creep properties in terms of stress to rupture and of temperature for 100,000 hours life.

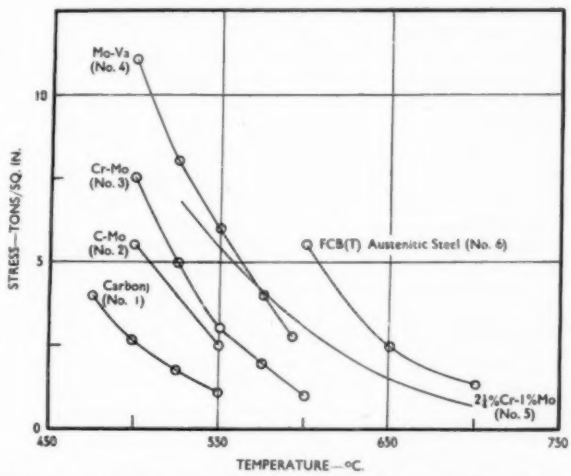

Fig. 1.—Rupture strength in 100,000 hr. of various pipe and tube steels.

Of the individual steels used to date, carbon steel (No. 1, Table I) has been used on a wide scale and has given excellent service, but its creep properties generally limit it to a maximum temperature of 850°–900° F. (454°–482° C.). Beyond this range, and up to 965° F. (518° C.)*, carbon-molybdenum steel (No. 2, Table I) and 1% chromium-molybdenum steel (No. 3, Table I) have also been used on a large scale with considerable success. On the whole, these steels have been trouble-

* See also British Electricity Authority Booklet "Power and Prosperity."

† For High Marnham Power Station—Steam Conditions 1,050° F. and 2,350 p.s.i.

* Highest steam temperature up to recent date.

TABLE I.—TYPICAL COMPOSITIONS AND HEAT TREATMENTS OF STEAM PIPE AND SUPERHEATER TUBE STEELS

Type of Steel	C	Si	Mn	Ni	Cr	Mo	V	Nb	Initial Heat Treatment
	%	%	%	%	%	%	%	%	
1. Plain Carbon	0·12	0·15	0·60	—	—	—	—	—	Normalised 900°–950°C.
2. Carbon-Molybdenum	0·10	0·35	0·60	—	—	0·50	—	—	Normalised 940° C.
3. 1% Chromium-Molybdenum	0·10	0·35	0·60	—	0·80	0·50	—	—	Normalised 940° C.
4. Molybdenum-Vanadium	0·10	0·25	0·60	—	up to 0·50	0·55	0·25	—	Normalised 975° C. Tempered 690° C.
5. 2¼% Chromium-Molybdenum	0·10	0·35	0·50	—	2·25	1·0	—	—	Annealed 940° C.
6. Austenitic (18/12/1 Nb type)	0·10	0·60	1·25	12·0	18·0	—	—	1·0	Air Cooled 1,050° C.

free, though some cracking troubles in steam pipes have been experienced both in the United States and Great Britain with the carbon-molybdenum type of steel. The American failures were attributed to graphitization[2], a phenomenon not experienced in British steam piping. The failures in this country were confined to one plant[3], but they have resulted in engineers using the chromium-molybdenum steel in preference to the carbon-molybdenum type, despite the otherwise excellent performance of carbon-molybdenum steel.

Published creep data are available for both carbon[4,6] and carbon-molybdenum[5,6,8] steels, with some of the results extending up to 70,000 hours. A useful summary of the results of work carried out by the National Physical Laboratory (1930–1952) on both types of steel is also available[7*].

Creep data for the chromium-molybdenum steel are not nearly so plentiful, but results available[8] indicate that there is little to choose between the two steels in terms of creep resistance, but that the chromium-molybdenum steel has superior creep ductility. This is one of the reasons why the chromium-molybdenum steel is finding increasing use.

Besides having the necessary creep resistance, steels for pipes and tubes should be weldable and easily manipulated. Hence they invariably have a low carbon content, which is also in the right direction for creep resistance.

The steels used for steam pipes are also in general use for superheater tubes, but whereas these latter rarely exceed a diameter beyond 2½ in. and, say, ⅜ in. in thickness, steam pipes may be made in sizes up to 12–14 in. diameter and 2½ in. thickness†.

The pattern of the more recent developments in steam plants has been greatly influenced by the impact of World War II, which for several years arrested all steam turbine construction and development work in this country. In an effort to make up the leeway, the British Electricity Authority took a courageous step in authorizing designs for steam turbines to operate at 1,050° F. (566° C.) steam and 1,500 lb./sq.in. pressure, an advance in steam temperature of approximately 100° F. Under more normal circumstances, operating experience with 1,000° F. (538° C.) steam would have been obtained before constructing these 1,050° F. stations. One 1,050° F. station is already in being, with several more under construction.

The selection of steels for the main steam piping is perhaps one of the most interesting features of these stations, since 1,050° F. is a borderline temperature in so far as the creep properties of ferritic steels are concerned. The choice lay between using certain of the better creep resisting ferritic steels or one of the austenitic types of steel.

There was a strong case for using a ferritic steel, if only because ferritic steels as a class had been used exclusively hitherto with considerable success, and, consequently, a large amount of service experience and general "know-how" was available. Compared with austenitic steels, ferritic steels are less costly, easier to weld and have lower expansion properties. If austenitic steels were used there would be a number of problems to be solved, not the least of which was the ability to make satisfactory welded joints. The main point in favour of the austenitic steel was its superior creep[10] and scaling resistance, and the fact that if steam temperatures were later advanced to, say 1,100° F. (593° C.) or higher, austenitic steels would have to be used if excessive pipe wall thicknesses were to be avoided (see Fig. 1).

In order to provide practical experience covering as many materials as possible, the B.E.A. decided to construct some of the 1,050° F. (566° C.) stations with austenitic steel pipe lines (Steel No. 6, Table I), and others with pipes of ferritic steel (Steel No. 5, Table I). The majority of the high temperature (outlet) superheater piping is being made in austenitic steel, while some of the superheater outlet headers involve the use of austenitic forgings some 30 ft. long.

U. S. Trends

It is of interest to examine the trend of power plant development in the United States, since, unlike the situation in Great Britain, turbine construction and development in terms of higher steam conditions continued throughout World War II. By 1948, several units with 1,050° F. steam and 1,500 lb./sq.in. pressure were in operation, typified by the plant installed at Sewaren, New Jersey[11]. Later, in 1953, 1,100° F. and 2,350 lb./sq.in. conditions were operating at Kearny[12, 13]. Apart from experimental plants, the unit operating with the highest steam conditions (viz., 1,130° F. (610° C.) and 2,280 lb./sq.in.) reported so far is in Germany[14]; this station has been in operation since 1951. A 16% chromium, 13% nickel, niobium-stabilised steel is used for the "piping" and the superheater tubing (high temperature end). The design of the piping in this station is unusual in that a cluster of 28 tubes (1½-in. bore × ½ in. thick) is used to connect boiler and turbine in place of a single pipe, in order to minimise thermal shock.

It is of interest[15] that a 275 MW. 4-cylinder turbine unit is being constructed in the United States to operate at the phenomenal advance conditions of 1,200° F. (649° C.) steam and 5,000 lb./sq.in. pressure, with a double 1,050° F. (566° C.) reheat at 1,050 lb./sq.in. and 250 lb./sq.in. respectively: initial operation will be at 1,150° F. (621° C.). It is stated that the boiler will contain about 150 miles of tubing, 80% of which will be in alloy steels.

The American approach to these higher steam conditions has been, in the main, to use low alloy steels for 1,050° F. steam piping and austenitic steels for 1,100° F. and above[16, 23]. Type 321* austenitic superheater piping has been used in both Sewaren and Kearny stations for the higher temperature stages. The Sewaren station uses 3% chromium-molybdenum steel† for its main steam piping (16¼-in. outside diameter × 2¾-in. wall), whilst that for Kearny is Type 347‡ (9½-in. outside diameter × 1⅝-in. wall). The Sewaren station has 6-in. diameter inlet steam piping (turbine leads) and stop valves in Type 347 steel. It is of interest that the piping used in both stations was produced from forged bar which was machine bored to size, whereas, in this

* Carried out under the auspices of the High Temperature Committee of B.E.I.R.A.

† Steam pipes are assumed to reach the steam temperature under steady operating conditions. It is the pipes connecting the superheater and the turbine inlet which are subjected to the highest temperatures and pressures, as far as the pipe work is concerned. The steam temperature at the turbine stop valve is usually adopted as the nominal steam temperature for the particular unit. In the case of the superheater tubes, metal temperatures are usually higher than the steam in immediate contact, and at the higher temperature end, or boiler outlet, the metal temperatures may be 50°–100° F. (or sometimes higher) than the nominal steam temperature.

* 18–8 titanium stabilised.

† Similar to 2¼% Cr 1% Mo (Steel No. 5, Table I), but with 3% chromium.

‡ 18–8 niobium-stabilised.

country, piping for the 1,050° F. stations is being produced by one of several hot deformation processes.

More recent power station designs in Great Britain incorporate a reheat or resuperheater section in the boiler which constitutes another method of improving thermal efficiency. In this case, the steam, after leaving the H.P. turbine, is reheated to some pre-determined temperature and then expanded through a separate turbine.

Several stations in this country are to operate with a steam temperature of 1,000° F. (538° C.), with reheating to the same temperature. The main steam piping is to be made from 2¼% chromium, 1% molybdenum steel in some cases, and molybdenum-vanadium steels in others. The 2¼% chromium-molybdenum steel is primarily an American development of the 1% chromium-molybdenum type of steel, and the creep properties (American sources[17]) are given in Fig. 1 for comparison with other steels.

Creep data available in this country extend to about 10,000 to 15,000 hours for the 2¼% chromium-molybdenum steel (Steel No. 5), and they appear to be in fair agreement with American data for the same period of time. One outstanding feature of this steel is its high creep ductility under creep rupture conditions, which is attributed to the fact that fracture appears to occur mainly in a transgranular manner.

Molybdenum-Vanadium Steel

Molybdenum-vanadium steel (Steel No. 4, Table I) has had limited use in steam plants to date, though it has been available for many years[8, 9]. The stress to rupture properties of this type of steel are also given in Fig. 1, from which it will be seen that molybdenum-vanadium steel is a little inferior to 2¼% chromium-molybdenum steel for the particular criterion being used. At low creep deformation, e.g., 0·1–0·2%, the position is reversed. Molybdenum-vanadium steel requires a careful control of composition and heat treatment in order to develop a good and consistent level of creep resistance and reasonable creep ductility. Incorrect heat treatment may result in a creep ductility value as low as 1–2%.

Until recently, molybdenum-vanadium steel was made without a deliberate chromium addition, but more recent steam pipe compositions include chromium up to about 0·5%. This addition improves hardenability and maintains the creep properties in larger sections. The presence of chromium is also regarded as an insurance against graphitization, though there seems little fear in this connection in so far as steels of British manufacture are concerned.

Molybdenum-vanadium steel has also a limited application in the United States, where a 1% chromium addition is made to the steel, primarily for increasing the resistance to graphitization[18]. The final heat treatment given to the steel differs in that the solution treatment is higher and the tempering treatment is longer :

Great Britain.—Normalise 975° C. Temper 690° C. for 3 to 6 hrs.

U.S.A.—Normalise 1,050° C. Temper 700° C. 16hrs.

The American treatment is designed to give a high level of creep resistance, and some of the published extrapolated values are well above those claimed for the molybdenum-vanadium steel used in this country. Examination of the actual test data available[18], however, does not support the claims made for it, the creep properties being no better than the British counterpart. Furthermore, the American heat treatment encourages low creep ductility, due to the higher solution treatment used.

Welding

Joining pipe lines by welding in place of bolted flanged joints has now been in general use for many years. With the introduction of the more recent advanced conditions, however, the quality and properties of the weld joint have assumed a much greater importance than hitherto.

British practice, in general, has been to weld carbon-molybdenum and 1% chromium-molybdenum pipes with carbon-molybdenum weld metal, but the practice in the United States[19] has been to use a weld metal of similar composition to that of the piping, including the newer 2¼% chromium, 1% molybdenum steel. In this country 2¼% chromium-molybdenum piping is being welded with electrodes designed to give a deposit of similar composition, and also with electrodes depositing a 1% chromium-molybdenum composition.

Welding molybdenum-vanadium piping with a weld metal of similar composition has proved difficult in regard to providing a sound weld with the desired creep properties[16] : low creep ductility is also a major difficulty. Little has been published in this country regarding the creep properties of ferritic weld deposits and welded joints.

Considerable work has been done, both here and abroad[19–23], on the difficult problem of welding austenitic steels in the form of heavy sections. Up to the present attempts to weld with a fully austenitic steel deposit have failed, though claims[24] have been made that this problem has been overcome. Heavy weld deposits in the fully austenitic condition invariably contain micro-fissures, and the solution has been to utilise electrodes which will deposit a composition giving a duplex austenitic/ferritic structure. It appears that the austenitic structure is hot short at very high temperatures, but a ferritic structure possesses high ductility at these temperatures. Also the presence of some ferrite in an austenitic structure appears to assist in dispersing carbides from the primary austenitic grain boundaries, which may increase resistance to cracking[25]. A few per cent. of *delta*-ferrite at room temperature ensures that at least 25% is available just below the freezing point, which is sufficient to prevent cracking. It is necessary to restrict the amount of *delta*-ferrite to, say, 7–8% maximum at room temperature, in order to avoid the formation of excessive amounts of *sigma* phase and consequent loss of normal tensile ductility with exposure at elevated temperatures.

The following are the approximate percentage compositions in use as weld metal :—

		C.	Si.	Mn.	Ni.	Cr.	Mo.	Nb.	Cu.
Great Britain	1	0·08	0·6	2·0	9·0	17·5	2·0	—	—
	2	0·08	0·2	1·0	10·0	20·0	—	0·85	2·0
United States		0·08	0·5	1·5	10·0	19·5	—	0·85	—

Even with a rigid control of composition to ensure the correct amount of *delta*-ferrite is present in the deposit, the welding of austenitic steel piping remains a highly specialised job requiring considerable skill and experience.

The author has been associated with a creep test programme being carried out on one of the compositions (No. 1) given above, and the creep results obtained at 650° C. are given in Fig. 2. Comparison is made with

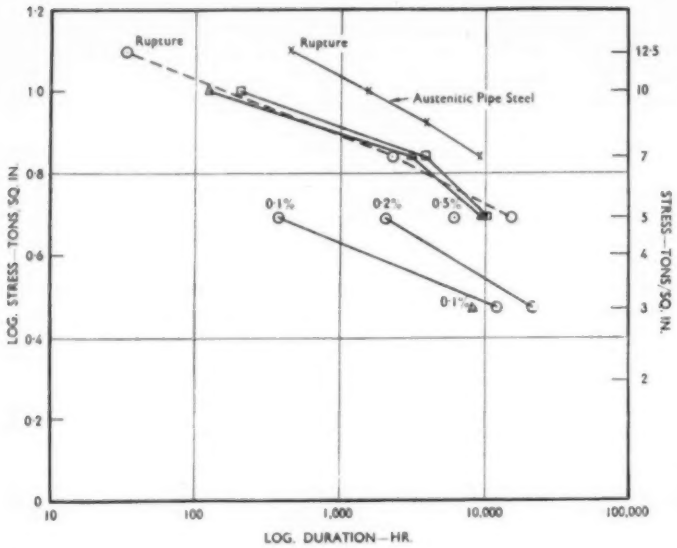

Fig. 2.—Creep test results on weld metal (17·5% Cr, 9% Ni, 2% Mo) compared with wrought austenitic steel (Composition No. 6, Table 1).

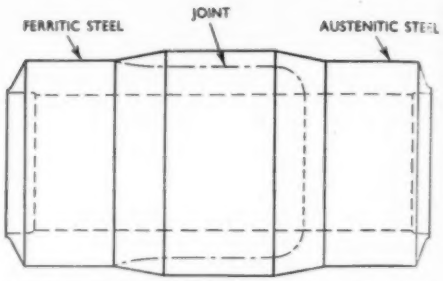

Fig. 3.—Austenitic/ferritic transition piece [27].

⊡—As welded condition.
△—After 3 hrs. at 750° C. stress relieving treatment.
⊙—After 5 hrs. at 800° C. stress relieving treatment.
×—Austenitic Pipe Steel Composition—A.C. 1,050° C. condition.

the stress-to-rupture results obtained on wrought austenitic steel bar of similar composition to that being used for steam pipe. The weld metal is a little inferior to the wrought material, but there is some evidence that the results will be comparable at the lower end of the stress range. Creep ductility of the weld metal compares favourably with that of the 18/12/1 wrought material.

In a number of cases where austenitic steel piping has been used, it has been necessary to weld it to a ferritic component. Apart from the actual joining operation, some thought has had to be given to the effect of the thermal stresses which arise when such a joint is heated. Various joints have been devised and subjected to a number of heat cycles in order to test resistance to thermal fatigue[28-29]. Consensus of opinion at present is against using a plain butt joint, and the type of joint generally favoured is one illustrated in Fig. 3. This type of joint is being used in British, American and German power stations. The American transition piece is made as a compound casting, whereas the German[14] and the more recently developed British pieces use wrought steels joined by pressure welding methods.

Turbine Rotors

Turbine rotors may take the form of a solid forging—turbine wheels integral with the shaft—or a built-up assembly in which separately forged discs are shrunk on to the shaft. High and intermediate pressure shafts are made from solid forgings, but not exclusively, while the low pressure shafts are often of the built-up type, though solid forged shafts are sometimes used. Each turbine manufacturer has evolved designs and constructions which possess their own distinctive features, and a certain amount of published information is available on this aspect[30, 31].

A review of turbine shaft materials and future trends was made by Sykes[32] in 1947. In general, the problems discussed at that time are largely operative to-day. The type of compositions in general use are listed in Table II.

Where creep problems exist, they are usually associated with the high pressure and reheat turbine shafts only, but it is with the introduction of 1,050° F. steam that creep resistance has really assumed a major significance in design. This probably accounts for the lack of long-time creep data on most of the rotor steels, though some short-time data are available in most cases.

The higher steam temperatures, coupled with the introduction of reheat, have increased the demand for turbine shafts with better creep properties, and increasing use is being made of the molybdenum-vanadium type (Steel No. 8, Table II) for forgings up to 40 in. diameter.

This type of shaft may be supplied either in the normalised and tempered or oil hardened and tempered condition, and studies are now being made of the creep behaviour at various positions in a forging. The best all-round creep resistance for molybdenum-vanadium steel is obtained when the steel is in the tempered bainitic condition, but the size of the forgings in question makes it impossible to achieve this type of structure in the central regions, even when 1% chromium is added and oil quenching is employed. Therefore, it is essential to ascertain the creep behaviour of a tempered pearlitic structure, which is the structure of a large proportion of molybdenum-vanadium rotor shafts of 30–40 in. diameter. For higher metal temperatures than at present contemplated, it may be necessary to give consideration to steels having greater hardenability with a high creep level.

The molybdenum-vanadium composition used for rotor shafts differs from the pipe steel in that the carbon content is rather higher, but this does not appear to have an unfavourable effect on creep resistance. The author is associated with some creep tests being carried out at 1,000° F. (538° C.) for long periods on material from the outside of a rotor shaft, and the results to date are given in Fig. 4.

Permissible creep for turbine shafts is generally limited to 0·1%.

There are not likely to be any marked changes in materials for low and intermediate pressure shafts in turbines which do not use reheat steam, but the higher creep resisting grades of rotor shafts will probably be used in some reheat turbines, partly on account of the temperatures and the higher stresses which are generally associated with this type of turbine.

TABLE II.—TURBINE ROTOR SHAFT COMPOSITIONS

Type of Steel	C %	Ni %	Cr %	Mo %	V %
1. Plain Carbon	0·40	0·25	0·20	—	—
2. Carbon-Molybdenum	0·32	—	—	0·60	—
3. 1½% Nickel	0·35	1·25	—	—	—
4. 3% Nickel	0·35	3·0	—	—	—
5. Chromium-Molybdenum	0·35	—	2·0	0·55	—
6. 3% Chromium-Molybdenum	0·30	—	3·0	0·45	—
7. Nickel-Chromium-Molybdenum	0·25	2·25	0·40	0·45	—
8. Molybdenum-Vanadium	0·22	0·30	up to 1·0	0·70	0·28

TABLE III.—TURBINE BLADE COMPOSITIONS

Type of Steel	C %	Cr %	Mo %	Ni %	Ti %
1. Stainless (Iron)	0·10	13·0	—	—	—
2. Stainless	0·28	13·0	—	—	—
3. Stainless Iron + Molybdenum	0·10	13·0	0·50	—	—
4. Austenitic	0·10	18·0	—	8·0	0·5
5. Austenitic	0·30	11·5	—	35·0	—

TABLE IV.—BOLT STEEL COMPOSITIONS

Type of Steel	C %	Ni %	Cr %	Mo %	W %	V %	Nb %
1. Chromium-Molybdenum	0·40	—	1·25	0·75	—	—	—
2. Molybdenum-Vanadium	0·20	—	up to 1·0	0·70	—	0·28	—
3. 3% Chromium-Molybdenum-Tungsten Vanadium	0·20	—	3·0	0·50	0·50	0·75	—
4. 12% Chromium Creep Resisting	0·12	—	10·5	0·75	—	0·15	0·45
5. Austenitic	0·10	12·0	18·0	—	—	—	1·0
6. Austenitic	0·25	18·0	16·0	2·5	—	—	2·0 Co 7·0

British turbine designers have so far avoided the use of austenitic steels for high pressure rotors. Experience with large gas turbine rotors in this type of steel indicates that their manufacture is both difficult and uncertain, and there is still much to learn in this direction. Attempts are being made in the United States to use austenitic steel rotors in the 1,200° F. steam power plant mentioned earlier.

Turbine Blades

The majority of turbine blading used to-day is made from stainless martensitic and austenitic steels, the former predominating. Compositions in use are given in Table III.

Until recently there were few creep problems connected with blading, since maximum steam temperatures in service were only 950–965° F. with many units with steam temperatures well below this. It is only the first stage of the high pressure turbine which is likely to approach the nominal steam temperature and maximum metal temperatures will not exceed, say, 500° C., with the majority of stages well below this temperature.

Where creep properties are under consideration, the usual criterion is 100,000 hours life and, very often, a maximum creep deformation of 0·1%, and sometimes 0·2%, is demanded. In these terms, stainless iron (No. 1 in Table III) is limited to about 450° C. for, say, 5 tons/sq.in., and about 475° C. for 3 tons/sq.in., for 0·2% maximum creep deformation. With a molybdenum addition (Steel No. 3, Table III) the temperatures for the same criteria are raised to about 490–500° C. and 510–525° C., respectively. Beyond these temperatures there is no martensitic steel at the moment for which reliable values for very long times can be quoted, though

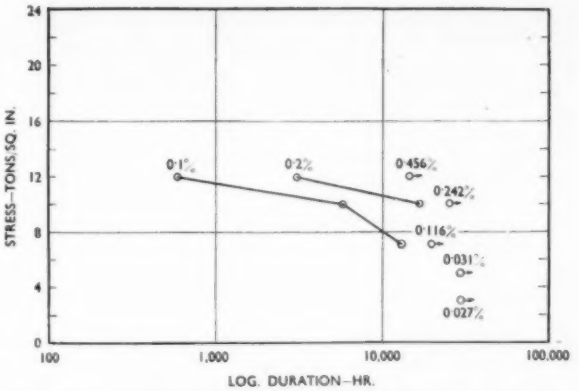

Fig. 4.—Creep test results obtained on material cut from the outside of a 28-in. diameter Mo-V steel rotor shaft. Temperature of test 1,000° F. (538° C)

there are several compositions which show considerable promise. Nevertheless, the author is of the opinion that the full potentialities of the stainless martensitic types have not been wholly appreciated, in that these steels have exceptional creep ductility associated with a long secondary creep phase. They also appear to fracture, under creep rupture conditions, in a transgranular manner, which is unusual for creep resisting steels. Thus, if only a fraction of the available creep ductility could be utilised, the service temperature could probably be raised some 20–25° C.

Bolt Steels

These are confined largely to the valves and turbines, as welded joints have superseded bolted joints in steam piping, except, possibly, at certain terminal points.

Prior to the introduction of the present advanced steam conditions, the 1% chromium-molybdenum steel (Steel No. 1, Table IV) was used almost exclusively for bolting, and this steel has given very satisfactory service over many years.

For 1,000° F. and, particularly, 1,050° F., steam, the 1% chromium-molybdenum steel has insufficient creep resistance for long service, and engineers have turned very largely to the vanadium-bearing steels. Bolts are now in service having compositions similar to Steels 2 and 3 in Table IV. It is estimated that these types of steel are about 50° C. better than the 1% chromium-molybdenum steel, but amongst themselves the vanadium-bearing types have a similar creep level.

As bolts are used in service under creep relaxation conditions, it is customary to test bolt steels using some form of stress relaxation creep test. The results obtained, however, are only relative, and it is seldom that they can be related directly to practice.

There is a need for improved ferritic bolt steels, particularly if steam temperatures advance still further. So far, any advance in creep resistance over the molybdenum-vanadium types has been largely at the expense of obtaining low or erratic Izod value, a property which many users consider to be undesirable in a bolt steel. 448 Steel (Steel No. 4) has had a limited application for 1,050° F. steam, but it has a low Izod value.

Where bolted joints are in austenitic steel, as in connecting a valve to a pipe, bolts of the 18/12/1 type (Steel No. 5) have been used. Some 1,050° F. turbines

have inner casings of austenitic steels and are also using austenitic bolts. One type of turbine is using 326 Steel bolts (Steel No. 6).

If steam temperatures increase, it may become necessary to adopt austenitic steel bolts on a more general scale, unless improved ferritic steels become available. The alternative would be to limit the life of existing ferritic steels.

Conclusion

Whilst this short review has dealt with several of the major items, it is by no means complete. Such components as casings, valves, and others, are subjected to high temperature steam, and these must be carefully considered in regard to the selection of suitable materials to withstand the service temperatures and pressures.

How far steam conditions will advance in this country is uncertain, particularly in view of the development of atomic power plants[33] which initially are to operate on relatively low temperature steam.

Acknowledgment

The author wishes to thank Dr. C. Sykes, F.R.S., for permission to publish this paper.

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Stress Corrosion Cracking of Gas By-Product Plants

ARISING out of a recent survey of 67 gas works installations where stress-corrosion cracking had been reported, the FM.9 Committee of the British Welding Research Association, although still awaiting the final analysis of the reports, believe that certain conclusions are justified.

(1) Stress-corrosion cracking is not limited to welded gas mains, but appears, though less frequently, in welded vessels.

(2) Its appearance has been found to be not related to any group of coals or any type of carbonising plant. No cases connected with water gas are known, and producer gas is not seriously suspected.

(3) The range of expected occurrence is now extended to include the foul main and terminate at the outlet of the final ammonia washers.

(4) Stress relief, by heat treatment, to a not unduly exacting specification, is apparently able to prevent its appearance entirely, and probably also to meet the effects of added strains such as arise from mechanical vibration, ground movement, etc., if these are not excessive. Shot peening has not been tested with equal thoroughness.

(5) Previously stress-relieved work should not be rewelded for alterations without afterwards restoring the stress relief.

(6) High quality of welding does not confer immunity, and there are some doubts in regard to riveted work being completely resistant.

The interim report conveying these conclusions has been circulated to the authorities directly interested in the manufacture of coke and gas.

Open-Hearth Flames and Output Report

A REPORT of the conference on "Open-Hearth Flames and Output," organised by the West of Scotland Iron and Steel Institute, held in September last year, will shortly be published. Its 96 pages record the full text of the five papers presented and the discussion thereon. Copies, price 17s. 6d. each, may now be ordered from the West of Scotland Iron and Steel Institute, 39, Elmbank Crescent, Glasgow, C.2.

Loewy Engineering Move

THE Loewy Engineering Co., Ltd., have moved to new Offices at Wallisdown Road, Bournemouth. The new telephone number is Winton 5000 and the telegraphic address is "Loewyworks Bournemouth." The company also has a new telegraphic address for its London office, which is "Loewyworks London."

Aluminium Casting Alloys

At a recent meeting of the Lancashire Branch of the Institute of British Foundrymen, Mr. R. Mercer of Enfield Rolling Mills (Aluminium), Ltd., presented a paper on aluminium casting alloys, with particular reference to alloys to B.S. 1490 : 1949 *and to the aluminium-zinc-magnesium alloys. A report of Mr. Mercer's lecture is presented here.*

ALUMINIUM casting alloys cover a wide field : it is, therefore, desirable to define the scope of this paper more precisely, which is to make the British Standard for aluminium alloy castings for engineering purposes, namely, B.S. 1490 : 1949, the basis, and to discuss the various alloys listed in it. Attention will also be drawn to a group of alloys with interesting properties which have been little used in this country.

At this stage it should be explained that the general usage in referring to both pure aluminium and aluminium-base alloys as " aluminium " is being followed. Strictly speaking this is not correct, of course, but this usage has probably developed as a result of the fact that the proportion of pure aluminium applied on its own is small, at least for castings.

History of Casting Alloys

B.S. 1490 was established after the last war to simplify the choice of suitable aluminium casting alloys for peace time engineering use from the multiplicity of specifications which had been drawn up before and during the war by the British Standards Institution, for aircraft (L specifications) ; by the Ministry of Supply (D.T.D. specifications) ; by the Light Alloy Control (L.A.C. specifications) ; and by manufacturers or as private purchasing specifications. It may, therefore, be interesting briefly to trace the historical development of aluminium casting alloys, and to compare the present standard with the early alloys.

The regular founding of aluminium began at the end of the last century, although the oldest known aluminium casting is a plaque cast in 1856 by Deville. The first " Alloy " if it may be called this, was pure aluminium, which is very little used nowadays, except for domestic and chemical utensils and for electrical applications. It appears in the standard as LM-0. Since pure aluminium is weak and soft and difficult to cast, it was first alloyed with zinc. This improved the strength, but increased the specific gravity considerably, and did not improve the castability. No corresponding alloy has been included in the standard. Replacing some of the zinc by about 3% copper gave an alloy of much greater strength and improved castability. LM-3 in the standard is representative of this type of alloy. Binary aluminium-copper alloys containing about 7% and about 12% copper were found to possess even better castability, and also to have better strength at high temperatures. LM-11 and LM-12 are modern developments of the type.

After the first world war, the National Physical Laboratories brought out " Y " alloy, which is included in the standard as LM-14. At roughly the same time, the eutectic aluminium-silicon alloy made its appearance, and became a useful member of the casting alloy family on the discovery of modification by Pacz. LM-6 is the corresponding alloy in the standard. During the twenties Rolls-Royce developed their aluminium-copper-magnesium-silicon-iron-nickel type of alloys, which require heat treatment to obtain their full strength. They are represented in the standard by LM-7 and LM-15. The aluminium-magnesium alloys made their appearance in 1929, their modern counterparts in B.S. 1490 being LM-5 and LM-10.

The developments since 1930 are so much part of recent history that they do not call for inclusion in this historical sketch.

Alloys to B.S. 1490

Like other British Standards, 1490 was drawn up by the industries concerned, and it therefore represents the concensus of opinion of the interested parties, obtained by compromise between differing views where necessary. This approach to standardisation is noticeable in the selection of the specifications for inclusion in the standard. Also, in accordance with its policy, the British Standards Institution merely lists the specifications, without indicating their relative importance or instructing the user in their respective purposes. It may, therefore, be of interest to examine the specifications in the standard from this angle.

Piston Alloys

When one considers the various specifications in order to group them according to their purpose, one finds so much overlapping that only one group stands out really clearly. This is the group of " piston alloys," comprising LM-12, LM-13, LM-14, and LM-15. The term "piston alloys " covers their most characteristic, although by no means their only, use. They are all heat-treatable alloys which maintain good strength and hardness at elevated temperatures. Of them, LM-13 is probably the most popular alloy, followed by LM-14, which possesses a greater strength at the highest temperatures than the other three : its castability is inferior to that of LM-13, however. LM-12 and LM-15 are more rarely used.

Other Alloy Groups

Since a satisfactory grouping of the remaining 17 specifications according to the purposes for which the castings are used is not practicable, an attempt will be made to split them into three divisions in accordance with their relative importance. In doing so, it is realised that this is a highly contentious enterprise, and that the division may be attacked and criticised strongly by many who see the importance of this or that alloy in a different light. Nevertheless, the writer will be well satisfied if a discussion of this subject ultimately leads to the elimination of unnecessary specifications from the British Standard, and thus to its simplification. Such a simplification would be welcomed by all sections of the aluminium alloy casting industry—refiners,

founders and user alike—and would be of real benefit in increasing the application of aluminium alloy castings.

The proposed three divisions are :—(*a*) specifications commonly used ; (*b*) specifications occasionally used ; and (*c*) specifications rarely used.

(*a*) *Commonly Used Specifications.*—In selecting the specifications which are commonly used, those alloys have been noted for which the Federation of Light Metal Smelters regularly publishes prices in the technical press. It is estimated that these four alloys represent in tonnage about 80% of the total consumption of aluminium casting alloys in the U.K. They are LM-1, LM-2, LM-4 and LM-6 (and the corresponding aircraft, D.T.D. and other specifications for the same types of alloys). Of the four alloys, LM-4 is easily the most important, followed by LM-6. Both are so well known that they require no description here ; they can both be used for sand castings, gravity die castings and pressure die castings. In importance they probably account for more than half the total consumption of aluminium casting alloys in the U.K. LM-1 is popular for castings where high mechanical properties are not required, and is used to best advantage for gravity die castings. It is quite fluid, although perhaps slightly inferior to LM-4 in this respect. It is greatly superior to the latter in its machining properties, however. LM-2 finds its main use in pressure die castings.

(*b*) *Occasionally Used Specifications.*—The specifications which are occasionally used, are, numerically, easily the largest division. The comprise, LM-3, LM-5, LM-7, LM-8, LM-9, LM-10, LM-11, and LM-18. Of these LM-8, LM-9, and LM-18 can perhaps be considered together, since they are all basically aluminium-silicon alloys. LM-18, with its lower silicon content, has better machining properties than LM-6, and is sometimes used in its stead where the lower strength does not matter, as in the food industry. The alloy can be sand, gravity die and pressure die cast. LM-8 is similar to LM-18, except for the addition of ½% Mg and ½% Mn for heat treatment. In castability it is slightly inferior to LM-18, but it is useful where its relatively high strength combined with its good corrosion resistance in marine atmospheres is an advantage. This alloy has come more to the fore recently and is, perhaps, the most popular of the medium strength heat-treatable alloys. LM-9 compares with LM-6, as LM-8 compares with LM-18 : it possesses much greater strength when it is fully heat treated, but its ductility is much lower. Its castability is similarly slightly inferior to that of LM-6 in die castings, although its fluidity is better than that of modified LM-6.

LM-5 and LM-10 can be regarded as forming another class, since they are of the aluminium-magnesium type of alloy, and both require to be made from high purity material : they are both used for sand and gravity die castings. Both alloys are useful for applications where colour anodising is important, since they take to this treatment particularly well. Castings to be anodised must, of course, be free from surface imperfections, such as inclusions and porosity. LM-5 is not an easy alloy to cast, and it is advisable to use in the sand an inhibitor against mould reaction, although its magnesium content is still low enough to allow it to be melted and cast under normal conditions : it is not heat treated. Its advantages include excellent corrosion resistance in marine atmospheres, good machinability, and ability to take a satisfactory polish. LM-10, when heat treated, gives the highest ultimate tensile stress and elongation of all the alloys in the standard. It is a difficult casting alloy, however, and requires an inhibitor in the sand against mould reaction. Unless special precautions are taken, it must be melted and cast under a protective flux or atmosphere. At the lower limit of the specification range for magnesium it is very difficult to obtain the minima laid down for mechanical properties in sand castings.

LM-11 is an aluminium-copper alloy, made from high purity materials only. Its castability is not good and, owing to its proneness to hot-tearing, it requires a special foundry technique. In mechanical properties it resembles LM-10, except in its lower ductility. It machines equally as well as LM-10, but its corrosion resistance is much lower. In comparing it with LM-10 it could be argued that it offers no advantage over this alloy, except for the special precautions necessary with the high magnesium content, and that its use might be discontinued in favour of LM-10.

LM-7 is used both in the as-cast and the heat treated condition. It is a rather complicated alloy, having copper, magnesium, silicon, iron, nickel and a grain-refiner as alloying elements. Its castability is quite good and it machines well.

LM-3 is an aluminium-zinc-copper alloy, and possesses the greatest strength and hardness of all the non-heat-treatable alloys in the standard : its machining qualities are excellent. It is fairly soft and ductile after casting, and attains its final strength almost completely after 21 days room temperature ageing. In a comparison of aluminium alloys with other foundry metals from the point of view of mechanical properties, it would appear as almost identical with cast iron.

(*c*) *Rarely Used Specifications.*—The specifications which are rarely used include the remainder of the standard, namely, LM-0, LM-16, LM-17, LM-19, and LM-20. Because of their infrequent application it is not proposed to discuss them any further here.

Modifications to B.S. 1490

Recently the specifications in the standard have been considered afresh and proposals have been made for minor amendments to some specifications; for the omission of two existing specifications, namely, LM-17 and LM-19; and for the addition of four new specifications, LM-21 to LM-24.

Of these, LM-21 is probably the most interesting, since its development is a typical example of the birth of a specification. It may, therefore, not be amiss briefly to trace its history. The change in the type of raw material available for the manufacture of the most popular casting alloy, LM-4, made it increasingly difficult to meet the relatively low zinc limit in the specification. A literature search revealed that the problem of the maximum allowable zinc content in some aluminium alloys had been investigated by Bonsack and Colwell in the U.S.A., and that the results of their research indicated that the existing zinc limit could safely be raised without affecting the alloy to any extent. Supported by the B.N.F.M.R.A., a joint body of founders and refiners conducted a series of co-ordinated experiments regarding the effect of zinc on the properties of LM-4 and confirmed the American experience. The results showed conclusively that a zinc content up to 2% had no effect on the mechanical properties and

TABLE I.—COMPOSITION OF THE ZC and ZG SERIES OF ALUMINIUM-ZINC-MAGNESIUM ALLOYS

	Alloy	Sand or Gravity Die Casting	Cu%	Mg%	Si%	Fe%	Mn%	Ni%	Zn%	Pb%	Sn%	Ti%	Cr%
(*a*)	ZC 60 A	G.D.	0·35–0·65	0·25–0·45	0·3	1·4	0·05	0·05	6·0–7·0	0·05	0·05	0·2	0·05
	ZG 61 B	S.	0·35–0·65	0·6–0·8	0·15	0·5	0·05	0·05	6·0–7·0	0·05	0·05	0·2	0·05
	ZC 81 A	S.	0·4–1·0	0·2–0·5	0·3	1·0	0·6	0·1	7·0–8·0	0·1	0·1	0·2	0·3
	ZC 81 B	G.D.	0·4–1·0	0·2–0·5	0·3	1·3	0·6	0·1	7·0–8·0	0·1	0·1	0·2	0·3
(*b*)	ZG 61 A	S.	0·3	0·5–0·65	0·25	1·0	0·3	0·05	5·2–6·0	0·05	0·05	0·1–0·25	0·4–0·6
(*c*)	ZG 32 A	S. & G.D.	0·2	1·4–1·8	0·2	0·8	0·4–0·6	0·05	2·7–3·3	0·05	0·05	0·2	0·2–0·4
	ZG 42 A	S. & G.D.	0·2	1·8–2·4	0·2	0·8	0·4–0·6	0·05	4·0–4·5	0·05	0·05	0·2	0·2–0·4

Single figures in this table are maxima.

Alloy designation according to A.S.T.M. Convention.

age-hardening characteristics. After the sponsors of these experiments had thus satisfied themselves that the proposed alloy was technically sound, a tentative specification was drawn up as ALAR 21 and the alloy used in ordinary foundry work. Its proposed inclusion in the British Standard, marks its official recognition.

LM-22 is an alloy of the LM-4 type with closely controlled copper and magnesium limits, and is intended for use in the heat-treated condition. LM-23 closely resembles LM-7 and is identical with B.S. Aircraft specification L.51. LM-24 is the British version of the American pressure die casting alloy SC.84.A. or S.A.E. 306.

Following this examination of the present standard specifications and the proposed additions to their number, the question arises as to how the standard would be simplified by retaining only those specifications which, by reason of their popularity or their useful combination of properties, can be regarded as really necessary. If the division of the standard into commonly used, occasionally used, and rarely used specifications is likely to meet with disagreement from some people, the suggested elimination of many specifications is certain to creat difficulties.

However, the following simplified standard of eight specifications is put forward as fulfilling all normal requirements: LM-1, LM-2 or LM-24, LM-3, LM-4 or LM-21, LM-6, LM-8, LM-10, and LM-13.

The inclusion of the four commonly used specifications requires no justification: for LM-2 and LM-4 alternative specifications are given, in case these should prove themselves more popular in the future, and ultimately replace the originals. LM-3 has been selected because it is the non-heat-treatable alloy with the highest proof stress after age-hardening, LM-8 because it is the most versatile medium strength heat-treatable alloy, and LM-10 because it is the heat-treatable alloy with the highest mechanical properties. LM-13 represents the alloys with good properties at high temperatures; it has the best castability of them all and is the most commonly used.

In this selection, the principle has been to prefer non-heat-treatable alloys to heat-treatable ones, those of better castability to those casting less well, those with higher corrosion resistance to those possessing this property to a lesser degree, and so on, under otherwise equal conditions.

Aluminium-Zinc-Magnesium Alloys

One class of aluminium casting alloys which has come very much to the fore since the war has not been included in the British standard, probably because their use is not common practice in this country. They are the aluminium-zinc-magnesium alloys, which have become established casting alloys in the United States. Many of them are covered by patents.

The theoretical basis of these alloys dates back to the early twenties, when Gurtler and Sander drew attention to the intermetallic compound $MgZn_2$ as capable of giving great strength to aluminium alloys without rapidly decreasing the ductility. A later development of this type of alloy was made by Comstock, who suggested the addition of chromium to improve the corrosion resistance and titanium as a grain refiner. Bonsack found a more powerful hardening agent during the thirties in the intermetallic compound $Mg_3 Zn_3 Al_2$.

The development of the aluminium-zinc-magnesium casting alloys thus falls into three classes:

(*a*) the alloys depending on $Mg Zn_2$ as hardening agent;

(*b*) the alloys depending on $Mg Zn_2$ as hardening agent, with the addition of chromium and titanium; and

(*c*) the alloys depending on $Mg_3 Zn_3 Al_2$ as hardening agent, which, by the way, also contain chromium.

Table I shows the appropriate specifications in their classes, together with their compositions. Table II gives the minimum ultimate tensile stress (to the nearest ½ ton) and elongation as given in the official specifications; they are shown in the cast condition after natural ageing. Typical values tend to be higher.

An interesting light on the relative importance of the various aluminium-zinc-magnesium alloys is provided by the American Metals Handbook. In the 1948 edition, only one is shown, namely, ZG 61 A, i.e., the alloy depending on $Mg Zn_2$ as hardening agent with the addition of chromium and titanium. The 1954 supplement lists three more alloys of this type: ZG 61 B, an alloy based on $Mg Zn_2$ as hardening agent, and ZG 32 A and ZG 42 A, both of which belong to the class making use of $Mg_3 Zn_3 Al_2$. It may be safe to conclude from this that the other alloys given in Table I are of theoretical interest only.

The mechanical properties at various temperatures may also be worth noting. As an example, ZG 61 A

TABLE II.—MECHANICAL PROPERTIES OF THE ALLOYS SHOWN IN TABLE I.

	Alloy	Sand or Gravity Die Casting	Ultimate Tensile Stress tons/sq.in.	0·2% Proof Stress tons/sq.in.	Elongation %
(*a*)	ZC 60 A	G.D.	12½		7
	ZG 61 B	S.	14	9	2
	ZC 81 A	S.	13½	10	3
	ZC 81 B	G.D.	14	10	4
(*b*)	ZG 61 A	S.	14	10	3
(*c*)	ZG 32 A	S.	13½	7½	5
	ZG 32 A	G.D.	16½	7½	10
	ZG 42 A	S.	14½	10	2
	ZG 42 A	G.D.	18½	11	4

Ultimate tensile stress and elongation are the minima as specified in the "as cast" condition, after natural age-hardening.
Alloy designation according to A.S.T.M. Convention.

TABLE III.—MECHANICAL PROPERTIES OF ZG61A ALLOY AT ELEVATED TEMPERATURES.

Temperature °C.	Ultimate Tensile Stress tons/sq.in.	0·2% Proof Stress tons/sq.in.	Elongation %
80	15	13½	3
120	13	11½	2
175	8½	7½	6
205	5½	5	10½

has the following typical properties at room temperature :

Ultimate Tensile Stress .. .. .. 15½ tons/sq.in.
0·2% Proof Stress .. .. 11 tons/sq.in.
Elongation 5%

These vary with the temperature as shown in Table III.

The composition of the alloys shows that they are made of high purity materials. Where copper is not a definite alloying element it is kept low, since it reduces the ductility and corrosion resistance. Silicon is probably the most important impurity and must be kept as low as possible, to avoid its combination with magnesium to form Mg_2Si. Iron tends to lower the ductility of the alloys, but its prescribed limits are not low in comparison with British specifications. The role of manganese does not appear to be clear, since it is kept to very low limits in some alloys, but added as an alloying element to others.

The aluminium-zinc-magnesium alloys are not unduly difficult to cast, although they are not so fluid as the aluminium-silicon alloys, of course : sections as thin as ⅛ in. have been produced successfully. Casting temperatures about 25° C. higher than for aluminium-silicon alloys are recommended, and more generous feeding arrangements will be found advantageous.

The advantages of these alloys lie in their unusual combination of properties. They possess high ultimate tensile and proof stress, combined with good elongation, without requiring any heat treatment. They are easily machined and take a high polish ; they are also easily anodised. Their corrosion resistance is said to equal that of any other aluminium alloy, and they are dimensionally stable after natural or artificial age-hardening. Owing to the relatively high solidus temperature (572° C.), they can be brazed successfully between 540° and 590° C. ; any loss in mechanical properties at the brazed joints will be recovered on subsequent ageing.

After about 3 weeks of natural ageing, the changes in mechanical properties become much less rapid, although they continue slowly for about a year. If it is desired to speed the natural ageing, this can be done by artificial ageing at 100° C. (in boiling water) for 8 hours.

In view of these advantages, the aluminium-zinc-magnesium alloys should be a useful addition to the range of alloys available to British founders to-day.

International Standards

Before concluding this short account of casting alloy specifications, mention must be made of the recent attempt to draw up international standards for casting alloys. The initiative came from a group of continental countries who invited, amongst others, representatives of the U.S.A., Canada and the U.K. An international secretariat consisting of all participating standardisation bodies was set up in Paris, and as an initial proposal international standards for the following 15 alloys were put forward : LM-1, LM-4, LM-5, LM-6 or LM-20, LM-7 or LM-23, LM-8, LM-9, LM-10, LM-11, LM-12, LM-13, LM-14, LM-16, A.S.T.M. ZG 42 A, and A.S.T.M. ZG 61 A.

Thus, many specifications of the British standard would be covered by the international standard, although it will, of course, be appreciated that the international specifications are by no means identical with the British. The advantages of having an international standard would lie in the export field, where competition for aluminium alloy castings would start from the same basis, and in providing such international bodies as U.N. agencies or N.A.T.O. with an agreed basis for any contracts which they may have to award.

Acknowledgments

Mr. Mercer concluded by expressing his thanks to those colleagues who had assisted in the preparation of the paper, and whose constructive criticism had proved most helpful. He was also greatly indebted to the Directors of Enfield Rolling Mills (Aluminium), Ltd., for their kind permission to publish it.

Modernisation at Banbury

THE Banbury Works of Northern Aluminium Co., Ltd., is now carrying out a modernisation programme planned to increase the output of sheet and strip by several hundred tons annually. Extensive remodelling of the remelting facilities is already under way to achieve this. The project is being undertaken at a time of steadily growing demand for the Company's products, and is expected to bring about a considerable increase in productivity. The present level of employment at the works will be unaffected.

Most of the equipment now in operation was installed in the period 1931–39, and the many subsequent developments both in the uses of aluminium and in manufacturing methods have made re-equipping essential. Details have been worked out by the Company's engineering staff in collaboration with equipment manufacturers after studies lasting several months. Owing to the importance of maintaining full production the programme will be accomplished in a number of separate stages, the last of which is not scheduled for completion until 1958.

The modernised mills and melting shop will incorporate the latest equipment designed to achieve high volume output, including a larger and more powerful hot mill capable of rolling ingots of over a ton in weight. Melting furnaces are being overhauled and modernised, and improved re-heating equipment will also be built.

It will be recalled that Northern's other major fabricating plant—at Rogerstone, Mon.—was expanded and remodelled in 1950 to roll building sheet, foil stock and light gauge strip products. The modernised works at Banbury are expected to complement this range and, as in the past, will produce a large proportion of high strength alloys for use in the aircraft industry and in other important fields.

Symposium Postponed

THE Institution of Mining and Metallurgy announce that it has been necessary to postpone the Symposium on the Extraction Metallurgy of some of the Less Common Metals which was to have been held in September, 1955. This will now be held in London on Thursday and Friday, March 22nd and 23rd, 1956. Further particulars will be published later.

Kemano-Kitimat Aluminium Project

New Capacity Will Benefit U.K. Aluminium Industry

General aerial view of plant and harbour installation at Kitimat.

THE aluminium industry is presenting a progress exhibition at the Royal Festival Hall, London, from June 1st to June 11th, 1955, to commemorate its centenary as a commercial metal, and to depict how the present production and experience gained are being applied to industry in increasing measure. The employment of this light metal is still in the relatively early development stages, but even so it is already the most widely used non-ferrous metal in the world, ranking second only to steel in volume. The existence of aluminium was established by Sir Humphrey Davy in 1808. In 1854 the French savant, Henry St. Claire Deville, produced the metal in minor amounts by chemical means. Further manufacturing improvements effected in association with H. Y. Castner brought its price down from $17 to $8 a pound. There it remained a standing challenge to metallurgists—an extremely useful metal, potentially plentiful, but too expensive for general use.

The advent in 1886 of the Hall-Héroult process for the electrolytic reduction of aluminium sent its price tumbling to $2 a pound—the first step in a descending spiral which 50 years later set the figure below 20 c. a pound. In 1886 the world production of $8-a-pound metal was 17·5 metric tons. In 1952, with its selling price below 20 c. a pound, the total free world output (excluding Russia and satellites) was 1,770,000 tons.

The discoveries which brought about low-cost aluminium production did not lead directly to widespread use of the metal. Manufacturers nurtured in the traditions and skilled in the use of older metals—iron, copper, steel, etc.—were slow to grasp the potentialities of this versatile, lightweight metal. During its first half century the aluminium industry was compelled to pursue the dual role of improving and enlarging production processes to reduce price, and, at the same time, proving its worth and feasibility in a wide range of markets. Its basic properties are admirably adapted to the needs of the modern age in terms of speed, economy and efficiency. Aluminium is light, strong (when alloyed with copper, manganese, etc.), and corrosion resistant. Moreover, it possesses high electrical and thermal conductivity, is easily fabricated, and has a pleasing appearance. Endowed with these desirable characteristics, it lends itself to effective and economical use in a wide range of applications. These factors have made possible the evolution of this light metal from a scarce, semi-precious commodity to an inexpensive and versatile necessity, leading all non-ferrous metals in volume. Market surveys suggest that its prospective free world demand may go up to 3,100,000 tons in 1960.

It was announced last month that another $190 million are to be spent on expanding the productive capacity of the Kitimat smelter to 330,000 tons a year—more than double the capacity now in operation or under construction. This outlay includes some further expansion of alumina production facilities in Jamaica, apart from the immediate expansion revealed earlier in the month, to 300,000 tons a year, an increase of 70,000 tons.

Benefit to U.K.

Based on this upward trend in consumption, the Aluminium Company of Canada (Alcan) decided early in 1951 to proceed on an integrated project on the basis of a power development entailing equipment for 450,000 h.p. firm capacity, transmission facilities, aluminium reduction unit, town and port in British Columbia. It was scheduled to advance in stages with an initial yearly capacity of 83,000 metric tons and an ultimate goal of 500,000 tons. The contract for the smelter expansion at Kitimat had been awarded to the Saguenay-Kitimat Company. Construction started in February (1955), and the additional smelter of 60,000 tons a year capacity, is scheduled for completion in 1956.

The Kemano-Kitimat undertaking is the largest unified power and aluminium development ever launched by private capital. Whereas the entire free world production of this light metal was 435,000 metric tons in 1937,

Looking up-stream through penstock access tunnel, showing Pumpcrete equipment.

General view of power house looking north-east from inner end of access tunnel.

the Kitimat smelter alone will, on completion, have an annual capacity of 500,000 tons. Its production should greatly benefit the British aluminium fabricating industry, as well as those of the Commonwealth and several foreign countries. The U.K. Government advanced $120 million to Alcan, $67 million of which have helped to finance this company's post-war expansion projects in British Columbia and elsewhere totalling $465 million. In return, Alcan accorded Britain the first call on substantial tonnages of ingot metal yearly until 1971. The United Kingdom leans heavily on Canada for its supplementary aluminium supplies, inasmuch as it lacks adequate resources of low-cost electric power to enable it to produce the huge quantities of the virgin metal it consumes. In 1953, for example, Britain produced only 34,000 short tons of aluminium and imported 184,000 tons from Canada.

Bauxite, the principal aluminium ore of commercial grade, is found mainly in tropical and sub-tropical territories, although minor deposits occur in areas fringing the sub-tropics. Close on four pounds of this raw material are required to produce one pound of the metal. Even more important, the output of aluminium ingot consumes approximately 10 kWh. for every pound of metal. The spark that launched aluminium as a commercial commodity and drastically brought down its price was electricity. The cost of power is of paramount importance to its economic output. An increase of only one-tenth of a cent (one " mill ") per kWh. in power cost, means 1 cent per pound increase in the price of the metal. Such an addition to cost would represent $22, or 5% on a selling price of $430 per metric ton. This may make all the difference to a manufacturer striving to compete with older and well-established non-ferrous metals on a price basis. The ideal location for aluminium production is one combining substantial blocks of continuous water power capable of being developed at reasonable capital cost, absence of competing demand, favourable transport facilities for the assembly of raw materials and access to markets. All these conditions are satisfactorily met by the Kemano-Kitimat project.

Built on Delta

The aluminium reduction plant (smelter) was built in part on the delta of the Kitimat River, and in part on alluvial fans deposited on the edge of the delta by two creeks discharging from the mountain slopes to the west. The difficulties of construction on this delta site were outweighed by the advantages of locating the smelter close to tide-water permitting easy shipment of the metal. The river required dredging and it was decided to level the smelter site on the delta using the gravel from the river bottom as part of the fill. Eventually 2,000,000 cu. yd. were pumped in hydraulically from the river bed and an additional 1,800,000 cu. yd. were brought in by trucks from a site two miles from the smelter. This fill reached a depth of 30 ft. in some places on the smelter site. For the next row of buildings, it is estimated that a further 1,000,000 cu. yd. will be needed. The levelling of the site was accompanied by the construction of the first rows of pot-line buildings, where the alumina is electrolytically reduced to the metal. Inasmuch as the building schedule did not permit natural settlement before erection, a forecast was made of the settlement likely to take place and the construction of structures was planned accordingly. The tall structures were built on a slight angle to permit future settling of the fill, and eventually they will become perpendicular.

The first section of the smelter, where the initial 90,000 tons of aluminium is produced is about half-a-mile in length. Further expansion was allowed for during the original filling in of the delta. Plans were laid in 1954 for the completion of the second section: when completed it will increase the length of the entire smelter by two miles. Vast quantities of cement were utilised in the construction of the foundations for each pot-room. The total length of the two new pot-lines and subsidiary buildings is about 1,230 ft. and their

Ferranti transformer in transit to the transformer vault at the north end of the power house inside Mount DuBose at Kemano.

H.R.H. The Duke of Edinburgh reaches to lift one end of an aluminium ingot on the occasion of the first pour at Kitimat.

width around 1,000 ft. From the concrete base rises a steel framework covered with aluminium sidings, and the entire structure is sheltered by an aluminium roof, also on a steel framework. No heating is necessary to overcome the cold of winter, since all heating is effected by the pots themselves. Each building is ventilated by power fans situated on the roof, and exhausts from the pots meet in one main duct running along the side of the structure. This duct carries the fumes through gas scrubbers servicing two buildings at a time. Workshops have been erected near the buildings and all maintenance and repair work is carried out in them.

In addition, large structures with a steel framework and aluminium roof serve the entire smelter as storage for alumina and calcined coke. One building has storage capacity for 20,000 tons of coke and the other for 30,000 tons of alumina. There is a conveyor gallery running direct from the wharf to the pot-line buildings nearly 4,000 ft. away and a conveyor belt inside the gallery will ultimately serve the whole area. Deliveries of alumina started early in 1954, together with all the other materials required for aluminium production. When the project is completed, it is computed that 20,000 tons of steel, 24,000 tons of aluminium and 4,000 tons of copper will have been used.

Power Supplies

At Kitimat, the terminal station is similar in arrangement to that at the generating station, except that there will eventually be 12 step-down transformer banks, each normally supplying a single pot-room, with bussing facilities to permit transfer of power to other loads; a bank for miscellaneous load; and a spare one. For communication between Kemano generating station and the Kitimat aluminium-reduction plant, power carrier facilities have been installed. The step-down transformer banks are single-phase O.F.W. type transformers rated at 37,000 kVA, with a voltage ratio of 275/13·2 kV, with four 2·5% taps, the neutral being solidly grounded. Each cell-line or pot-line is supplied by eight mercury-arc rectifier equipments, of the ignitron type in the initial establishment, each rated at 12,500 kW. These comprise a single-tank, 1,200 amp., 1,000,000 kVA interrupting capacity, outdoor oil circuit breaker; a self-cooled phase-shifting transformer rated at 13,200 kVA (of which two provide 15° phase shift, four 7·5° shift, and two 0°) and arranged to give 48 phase operation; a self-cooled rectifier transformer rated 13,200 kVA, with a three-phase primary and two six-circuit Y-connected secondary windings. These 12 windings supply the 24 anodes of two rectifier frames, each consisting of 12 pumped, ignitron-type, water-cooled rectifiers with auxiliaries. The cathodes of the 16 frames are connected through high-speed air circuit breakers to the positive main D.C. busbar. The neutral points of all secondary windings are connected to the negative D.C. busbar, through interphase transformers. The rectifier equipment is expected to have an efficiency exceeding 96%, from the 13·2 kV A.C. busbar to the 1,000-volt D.C. busbar.

Port Facilities

At the same time the development of port facilities was launched at the Kitimat smelter site at the head of the Douglas Channel, 80 miles from the open Pacific Ocean. Narrow, but deep, this channel provides ready and protected access to the sea. The port, as well as the smelter, began taking shape at the head of the Douglas Channel in 1952. Dredgers deepened the water at the wharf site, piling waste behind two rock moles to form suitable land for part of the smelter structure. Construction was launched on a 750-ft. wharf, designed for further expansion as needed and ample for berthing ocean-going vessels where tides rise 20 ft. An 8-ton Kangaroo crane and an unloading tower, specially designed for receiving bulk alumina at Kitimat, serve the ships docking at the new port. Conveyor belts move the incoming materials from the wharf to storage and thence to the pot-rooms, a total land transport distance of only 1,000 yds.

The first shipment of alumina left the Jamaican port of Esquival for Kitimat in May, 1954. Aluminium, Ltd., was the first company to explore and acquire bauxite properties and undertake substantial development work there. A subsidiary, Alumina Jamaica, Ltd., set up bauxite mining and alumina preparing facilities in the south-central sector of the island: the alumina processing unit will have an ultimate capacity of 600 tons a day. The establishment of this enterprise, entailing an outlay of $30 million, called for the construction of a deep-sea port to handle exports of alumina to the Kitimat smelter. When in full operation, the latter will need upwards of 100 cargoes of alumina annually. The saving in shipping by exporting alumina in place of raw bauxite is nearly 50%.

Integrated Community

As at the Arvida aluminium plant in Quebec, a modern town, planned for development by stages, is envisaged at Kitimat. This will embrace housing, schools, shops, recreation and health centres. Since no civic authority existed here at the outset, and so as to avoid haphazard development, the company engaged expert advisers, town planners and architects to help it launch an integrated community centre on a sound basis. Early this year (in 1955) Kitimat is reckoned to have a population of some 6,000, of whom nearly 700 will be operators and the rest employees' families and others engaged in service establishments and ancillary industrial activities. Once the municipality gets under way its supervision and future will be in the hands of its citizens.

Largest in the World

The outstanding features of the Nechako-Kemano hydro-electric power development project and ancillary facilities on which the Kitimat smelter relies for its operation, are briefly summarised thus: on completion it will be the largest underground power development in the world, having a firm capacity three-fold the ultimate installed capacity for Sweden's Harspranget development, and approximately 1·7 times that for Brazil's combined Forcacava No. 1 and No. 2 plants. It will then have an installed capacity markedly in excess of Boulder (Hoover) Dam, and be exceeded only by the Grand Coulee development of 2,250,000 kW. It will, however, have an annual firm energy generation well over the estimated 8,100 million kWh firm from Grand Coulee.

The Kemano-Kitimat project's vertical turbines will be the world's greatest capacity impulse type units. The 2,600-ft. head, 11-ft. diameter, pressure conduit is probably not exceeded by any other built or under construction today. The 300-kV oil-filled power cables will constitute the highest voltage power cables in service in North America, and the second highest in the world only exceeded by the 380-kV cables at Harspranget in Sweden. The transmission-system loading will be the world's highest by a substantial margin and the conductors the largest ever fabricated. Finally, the Kitimat reduction works will be the world's largest aluminium smelter when completed. Incidentally, half of the initial 300-kV power cable order, one of the original set-up transformer banks, one of the generators and part of the pressure-conduit steel for Kemano were procured from Britain. Moreover, half of the pot room cranes, the unloading crane for the harbour, and the bulk-alumina unloading equipment for this smelter emanated from the same source. Among the leading suppliers were English Electric Co., Ltd., Ferranti, Ltd., Pirelli-General Cable Works, Ltd., Stothert & Pitt, Ltd. and Simon Handling Engineers, Ltd.

Heavy Water Plant Order

Head Wrightson Processes, Ltd., have received an order from Geothermal Development, Ltd., for a heavy water plant to be erected in the Wairakei district of North Island, New Zealand. Members of Head Wrightson Processes' technical staff have visited New Zealand on various occasions to partake in discussions concerning this project with officials of the Government, and the Company has been working with the Atomic Energy Research Establishment, Harwell, on the development of this scheme for the past few years.

In addition to the heavy water plant, the Wairakei plant includes a power station, a compound unit and a water pumping station. Energy supply for the operation of this plant is by means of steam taken from hot springs at Wairakei, and separation of the heavy water is achieved essentially by distillation. The steam is also used in turbo-alternators to generate electric power. The heavy water plant has been designed so that each stage of distillation is performed in sets of fractionating columns operating in series, and careful consideration was given in the design of the plant to ensure that the appearance would be pleasing, merging harmoniously with the surrounding countryside. Cooling water for the turbines is to be taken by pipes from the Waikato river, and passed through sluice gates and screens before entering the pumps.

Lockheed Metallurgy in 1954

In a report on the company's activities during 1954, the Lockheed Aircraft Corporation, Burbank, California, lays emphasis on work in the metallurgical field. Research into the adaptability and utilisation of titanium in aircraft structures continued. Methods were developed for carrying out simple flanging operations in titanium by means of a hydraulic press. It was found that titanium could be readily drop-hammer formed at temperatures between 700° F. and 900° F. (370-480° C.), and a method for draw-forming deep beaded parts for cargo doors was also developed. Titanium is currently being employed by Lockheed in the engine nacelles of their new C-130 turbo-prop cargo transport.

Considerable research has also been undertaken with 17-7 PH stainless steel. This particular material can be hardened or strengthened by heat treatment, making it possible to form complex shapes in the annealed condition and subsequently elevate the strength to high levels. By virtue of this property it is now possible to design and manufacture complex, high-strength components which could not be formed in 302 and 347 stainless steel.

Integrally stiffened aircraft structures were pioneered by Lockheed, and in this sphere further progress was made during 1954. Special emphasis was given to the development of new techniques for stretching heavy plate to remove internal heat treatment stresses. The use of "stretcher-levelling" imparts 5% permanent set before heat treatment, and 2% after heat treatment and before ageing. This process has all but eliminated the warpage which has previously been associated with machined skins. Stub wing panels were stretched on an 8,000-ton Birdsboro press and, when subsequently machined, showed vastly improved flatness.

Reclaiming Zirconium Chips For Arc-Melting Feed Stock

When zirconium is machined, the chips are contaminated with such elements as iron, aluminium, silicon, carbon and oxygen, and remelting such material produces ingots whose hardness is higher than that of the original material. Techniques for the removal of the contaminants are discussed here.

THE reclamation of machined zirconium chips by a process of washing, leaching, and pickling, makes it possible to obtain a material of low hardness suitable as a feeding stock for arc furnaces. These reclaimed chips may be fed directly into an arc furnace or used as feed in the iodide process along with sponge. They are more valuable in the former process, however, and experiments with the chips have been conducted along these lines. During machining the chips are contaminated, and as a result the ingots produced from them are excessively hard. Iron, carbon, silicon and aluminium appear to be the elements picked up during machining.

The zirconium chips used in experiments reported here[1] were produced by milling and shaping operations. Soluble-oil coolant was used for milling but the shaping was done without a coolant. The chips were classified according to the way in which they were formed: face-mill, straddle-mill, Sharon-shaper, and Sharon-mill chips.

Chemical analyses were made to determine the degree of contamination. The chip types and several sets of analyses which are indicative of the contaminants present are shown in Table I. A typical analysis of iodide crystal-bar zirconium is included for comparison. The analytical data show that the elements present in significantly larger amounts in the chips than in the crystal bar are iron, aluminium, silicon, carbon, and oxygen. In two types of chips, considerable amounts of molybdenum were found, and in one, a considerable amount of magnesium.

It is believed that the aluminium and silicon, and possibly some of the iron, come from dirt: the balance of the iron may come from wear of the tools. The carbon represents traces of the cutting fluid left on the chips, and the oxygen is a result of oxidation of the hot chip during machining. It is interesting to note that little nitrogen is picked up by the chips. This observation agrees with published statements on the reaction of zirconium with air, namely, that reaction with oxygen occurs at lower temperatures than reaction with nitrogen.

1 F. W. Dayton, C. M. Allen, W. U. Eberts. Report No. AECD-3499, U.S. Atomic Energy Commission, Battelle Memorial Institute.

TABLE II.—EFFECT OF CLEANING PROCEDURE ON CARBON CONTENT OF STRADDLE-MILL CHIPS.

Cleaning Treatment	Carbon Content (p.p.m.)
Centrifuged, washed with CCl_4 with agitation	200
Centrifuged, washed with agitation	3400
Vapour degreased	2300
Soaked in hot nitric acid (30%)	700
Soaked in hot sodium hydroxide (20%)	800
Soaked in hot hydrochloric acid (20%)	900
Crystal bar	200

Thus, it appeared that some of the contaminants of the chips were mechanically held. This method of contamination would account for the carbon, aluminium, silicon and part of the iron. Another part of the iron and the oxygen would be constituents of a surface film on the chips. The mechanically held contaminants could probably be removed by mechanical operations such as washing, scrubbing, and agitation, but the remainder would have to be removed by removing part of the surface. Finally, the form of the chips would have to be altered before they could become useful arc-melting feed stock.

Removal of Cutting Oils

Centrifuging is an effective method of removing the bulk of the cutting fluid. In the laboratory this was done in a 14-in. basket at 3,400 r.p.m. for 15 minutes. The remaining oil is most effectively removed by solvent treatments. A half-hour wash in carbon tetrachloride and then in alcohol, followed by air drying, produced material with low carbon content, as shown in Table II. As will be seen in this table, other cleaning techniques were tried but were not so effective.

Removal of Adhered Contaminants

Even after removal of the oil, the other mechanically held contaminants remain, but agitation of the chips on a screen was effective in removing the bulk of the contamination. This was done in a gyratory riddle with openings of 0·017 in. by 0·060 in.; Table III shows the effectiveness of this operation. The effectiveness is also shown by the fact that some samples of the material passing through the screen contained as much as 5% of iron.

TABLE I.—ANALYSES OF ZIRCONIUM CHIPS AND CRYSTAL BAR.

Chip Type	Spectographic Analyses (p.p.m.)																			Chemical Analyses (p.p.m.)		
	Fe	Al	Si	Ni	Sn	Zn	Cu	Mg	Mo	Mn	Cr	Pb	W	Ti	Hf	V	B	Be	Co	Ta	N	C	O
Sharon shaper	1100	310	170	80	< 5	—	20	25	200	7	20	<10	<50	40	<300	—	1	1	6	<500	70	1300	—
Sharon mill	840	510	840	40	< 5	—	40	25	175	4	10	<10	<50	40	<300	—	2	<1	<5	<500	20	1200	—
Straddle mill	1600	300	140	40	<10	<100	20	400	<10	< 5	10	<10	<50	90	<300	<10	<1	<1	<5	<500	<20	700	1700
Face mill	700	700	80	5	<10	—	40	20	<10	5	<10	<10	<50	<10	<300	<10	2	<1	<5	—	30	1000	1000
Crystal bar	200	20	50	30	<10	—	5	<10	<10	<10	30	<10	—	20	<400	—	—	—	—	—	20	200	—

TABLE III.—ANALYSES OF ZIRCONIUM CHIPS BEFORE AND AFTER REMOVAL OF ADHERED CONTAMINANTS BY RIDDLING.

Chip Type	Analyses (p.p.m.)		
	Fe	Al	Si
Straddle mill (before removal)	1600	300	140
Straddle mill (after removal)	190	20	60
Face mill (before removal)	700	700	80
Face mill (after removal)	520	<10	50

Although this procedure is effective in removing most of the adhered contaminants, occasionally iron oxide still adheres to the chip surface. Its presence can be detected by shaking the chips in dimethyl ether, when any iron oxide will give a definitive red-brown suspension. The oxide can be removed by leaching in dilute hydrochloric acid (5 normal, 17–18%) and washing.

Removal of Oxygen Contamination

The oxygen contamination is confined to a thin surface layer on the chips, and pickling appears to be the only feasible method of removing this layer. Since no pickling solution is known which dissolves the oxide and not the metal, it is necessary to remove some of the surface of the chip. The ZrO_2 layer is then "lifted" from the chip surface. A certain loss of metal naturally must be tolerated, and this appears to be about 10%.

The pickling solution used contained 50 vol.-% of 70% nitric acid and water with an addition of 1% of ammonium fluoride. Pickling was carried on for about eight minutes, using 1½ gallons of pickling solution per pound of chips, and the chips were agitated slightly during the pickling to promote more uniform attack. This operation removed about 12–15% by weight of zirconium. The bath is replenished for further use by adding 0·20 lb. of ammonium fluoride per pound of chips treated. After pickling, the chips are rinsed thoroughly with cold water, then rinsed in alcohol and dried.

Small ingots were melted from these chips, and the hardness of the ingots measured, since this was a more convenient method than an analysis for determining the effectiveness of the oxygen removal. The data given in Table IV show that when 9% or more of the chip weight was removed by pickling, ingots of low hardness were obtained. The hardness is higher than that of the original zirconium, but not much higher than if the sheet stock had been remelted without machining.

Preparation of Melting Stock

Except for the straddle-mill chips, the chips used in this study were a "hay-like" mass. In this form, they are useless as arc-melting feed stock, so a few methods of preparing suitable arc-furnace feed were investigated.

The chips were subjected to several ball-milling tests using zirconium balls in a rubber-lined mill. This, however, was not satisfactory, since the grinding was not uniform, resulting in particles which ranged in size from fines which formed a suspension with the alcohol used as a protective fluid, to masses which were unchanged.

TABLE IV.—RESULTS OF PICKLING OPERATIONS.

Chip Type	Weight Loss, %	BHN* (3,000 kg.)
Straddle mill	8·6	115
	21·9	115
	24·7	117
	25·2	115
Face mill	6·1	164
	11·4	124
	22·2	115
Sharon shaper	6	108

* Hardness of ingots prepared from the treated chips was used as the criterion for oxygen removal.

An attempt was made to form solid charging stock by cold rolling $7 \times 1 \times 1\frac{1}{4}$ in. bars which were made by compacting the chips under a 10 tons/sq. in. pressure. This was unsuccessful since the bars split during rolling before solid material could be produced. However, these cold-rolled bars, when nibbled, gave sand-like fines which were dense enough to pour easily. The bars which had been compacted only could also be nibbled into fines of quite high density. A disadvantage of this method, however, is that it subjects the chips to processes in which they could readily pick up contamination. It might be possible to decontaminate the chips after producing the fines, and, in this form, they could be briquetted or poured into tubes of zirconium foil.

Arc Melting of Ingots

Almost all of the chips melted into ingots were prepared, after contamination removal, by compacting the chips in a ½-in. die. The slugs thus formed were used as feed stock for the arc furnace, and experimental ingots of 35–50 g. were usually melted.

To determine the more practical aspects of reclamation procedure, uncompacted chips were used to melt a 2½ lb. ingot and a 2 oz. ingot. The hardness of these ingots, 170 and 129 Brinell respectively, was considerably higher than that of the smaller ingots. Unfortunately, the melts became contaminated by the tungsten electrode and this was the most likely cause of the higher hardness. The tungsten contents were 1·2% and 0·4% respectively. The chips had a tendency to "float" against the electrode, leading to their contamination. Proper arrangement of the gas inlet and feed tube, and shielding the electrode may avoid this contamination.

Complete data on materials cleaned as discussed above are given in Table V.

TABLE V.—ANALYSIS LIMITS AND RESULT OF DECONTAMINATION.

	Analyses (p.p.m.)					
	O	N	C	Al	Fe	Si
Contamination limits	200	20	400	80	550	100
Prior to cleaning and pickling	1700	20	3400	300	1600	140
After decontamination	200	20	200	20	350	60
For comparison: crystal bar	—	20	300	20	300	50

Conclusions

These experiments have shown that it is possible to remove most of the surface contamination of zirconium chips and produce a material with essentially the same composition as the material from which they were cut. Thus, it should be possible to use the chips in the same manner as heavier zirconium scrap, as melting stock.

If the material is to be remelted, some method of consolidating the long stringy chips into suitable melting stock will be required. A little work on this subject has been done, and although no satisfactory method was developed, promising avenues of exploration were found.

The study was terminated in favour of large scale tests in chemical plants. For that reason, no detailed cost analysis of processing was made. It appears, however, that costs should be reasonable, the largest being the 10–15% metal loss in pickling.

Benjamin Huntsman

Clockmaker Pioneer in Casting Steel

By Eric N. Simons

Although several metallographers are immortalised in such phase names as austenite, martensite, sorbite and bainite, as are Bessemer, Thomas, Siemens and Martin in steelmaking terms, the name of the man who first produced cast steel is not so preserved, as the coke-fired crucible process is no longer a feature of the steel production picture. Prior to the time of Huntsman, however, steel was made by the cementation of wrought iron, and its properties suffered as a result of the slag streaks present in that material: his discovery was, therefore, a landmark in the history of steelmaking.

THE foundation of the modern fine steel industry was probably laid by Benjamin Huntsman in 1740, when he discovered a means of producing steel, of a quality superior to that in use in his day, by a process which has since come to be known as the crucible steel-making process. Huntsman, like that other great metallurgical genius, Abraham Darby, was a Quaker. He was the fourth child and third son of William and Mary Huntsman of Epworth in Lincolnshire. Mary's maiden name was Nainby, and there is a suggestion that his father was of German extraction (not, however, proved), who had been living in England a few years only when he married Mary Nainby, in 1698.

Benjamin was apprenticed to an Epworth clockmaker at a premium of £4, but his apprenticeship was of short duration, because in 1725 he set up in business in Doncaster on his own account, with an apprentice named Davey William Harrison at the high premium, for those days, of £20. In addition to looking after the interior mechanism of clocks, Huntsman also carried on a fairly extensive trade in the making and mending of locks, smoke-jacks, roasting-jacks, and so forth. Some of his pendulum clocks were still in existence in 1863, it is said, and one still stands in good running order in the office of Messrs. Benjamin Huntsman Ltd., Sheffield, though its authenticity is not certain. It was shown by the owners at the British Empire Exhibition, Wembley, in 1924.

From all accounts, Huntsman was a wise, observant, ingenious and clever man, who speedily acquired a local reputation for wisdom far exceeding that of his neighbours. He was considered not only expert in repairing clocks, but also in solving problems connected with the mechanism of the human body. He actually practised surgery of a sort, and was particularly successful as an oculist. People came to him for advice in connection with many diseases requiring surgical treatment, but it is said that he never accepted a penny-piece for his labours in this field, whether because his conscience would not let him, one cannot say.

Poor Spring Steel

Always inventive, he introduced many tools that were improvements upon those in vogue in his trade. His business and experiments were, however, continually handicapped by the poor quality of steel available, which was mainly a common steel from Germany. He found it by no means easy to find a suitable material for the springs and pendula of his clocks, and in exasperation at the continual trouble experienced, set to work to produce a better.

He was married in 1729 to Elizabeth Haigh of a family from Carlcoats, near Doncaster. The marriage, incidentally, was a Church of England one, despite Huntsman's being a Quaker, and there seems to be reason to suppose that it was a runaway match. The place of the marriage was either Retford or Tuxford, but more probably Retford. They cannot have lived in Retford for any length of time, because in 1729 there is a written record that they were living in Doncaster. Two children were born to them, Elizabeth and William. According to a tradition of the family, William's mother had him baptized in an Anglican church in Derbyshire, and there

Fig. 1.—Clock by Benjamin Huntsman reputed to contain the first successful results of his invention of crucible cast steel.

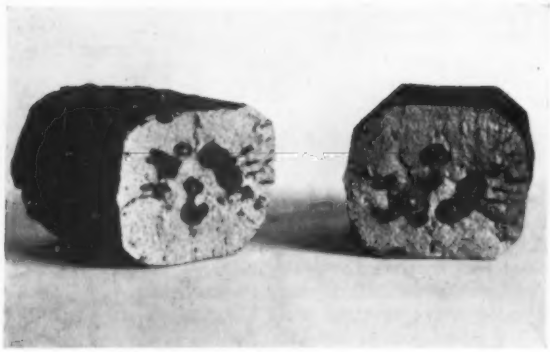


Fig. 2.—Rejected ingots of Huntsman's steel unearthed when the works were transferred from Worksop Road, Sheffield, to the present site.

is a record of such a baptism at Penistone in the West Riding, on the Derbyshire border. It is said that his wife's conduct so annoyed Benjamin that he would have no more to do with her. They separated, and she died in 1760, six months before her daughter's marriage.

In 1735, Benjamin Huntsman is recorded as undertaking to look after the Doncaster town clock "till the 1st May." For one and a quarter years at this, he received thirty shillings. He also received £1 18s. 6d. for "clock-string," (i.e. the line bearing the weight in weight-driven clocks). He had a tenement in High Street, Doncaster, of which in 1739 he bought the freehold from Richard Burden for £210, but he sold it again in 1740 for £200.

It is known that his first researches into better steel were carried out at Doncaster, but that district was not the best for the purpose, owing to the difficulty of obtaining fuel. Until recently it has been supposed that he migrated from Doncaster to Handsworth, near Sheffield, in 1740, but Mr. Wyndham Hulme has shown that in 1743 he was still in Doncaster, as witness his taking of a second watch-making apprentice, John George Hodgson, in 1743, in Doncaster, at a premium of £3—probably for a short term.

Not only economic considerations may have moved Huntsman to leave Doncaster. There were Quaker families in the Sheffield district, and he doubtless preferred to reside among people of his own denomination. At all events, we must abandon the date of 1740, and fix upon 1744 as the earliest date for his move to Handsworth.

Secret Experiments

All Huntsman's experiments were strictly secret, and he kept no written records of his various efforts. Consequently, one can but vaguely conjecture how far at that date he was on the road to his remarkable discovery. His problem was an extremely complex one. He had not only to find a fuel and a flux that would meet his needs, but also to build both a furnace and a crucible that would withstand a degree of heat greater and more intense than had previously been encountered in metallurgy as he knew it. He had no ingot moulds, no hoops and wedges to hold them together, such as are common in crucible-steel-making plants, but he persevered and was eventually successful.

We have, however, still preserved at the Huntsman works, Sheffield, some old rejected ingots of his steel, unearthed at the time when the works were transferred from Worksop Road, Sheffield, to their present site. The illustration shows two of these. They are obviously defective and are at least 180 years old. They show a coarse, crystalline structure, but as the steel has not been analysed, its composition cannot be exactly stated. The carbon content is known, however, to be in the region of 1%. Some other ingots discovered at the same period reveal many flaws, owing to the fact that the use of aluminium in "killing" steel and of the "dozzle" in preventing pipe was not then known.

Throughout his experiments, Huntsman refused to abandon his primary notion of purifying the crude steel then in common use by melting it with fluxes at an intense heat in closed earthen pots. Some of his failures arose from bad melting, some from fracture of the crucibles, some from poor fluxes.

What drove him on? There cannot have been enough clock-making in the world at that date to provide a sufficient market for the new steel such as would recompense Huntsman for his heavy expenditure on research and experiment. It seems reasonable to suppose that as a shrewd man, with more than ordinary intelligence and foresight, he realised the wide and varied uses to which a better steel could be put. In fact, almost immediately after his steel was perfected, he began to badger the cutlers of Sheffield into using it for their knives and razors. The cutlers, as always conservative and reactionary, would have nothing to do with it, because it was harder than any steel they had had to deal with before, and, therefore, needed more work. Huntsman gave up the idea of finding a market for his new steel in this country, and began to sell it abroad.

French Encouragement

The French were quick to see the value of crucible steel, and began to consume the entire output of the Huntsman furnaces. Knives, razors, etc., of this steel were so much better than those made with cheaper steel that even English buyers ordered their requirements from France, because that was the only way of getting them in the new steel. The Sheffield cutlers were worried, but rather than admit they had blundered, they tried the easy way of getting Parliament to stop Huntsman from exporting his steel.

The M.P. for the county of York, Sir George Savile, was a man of sense, and he would not encourage the childish behaviour of the cutlers. Tempting offers were made to Huntsman by the men of Birmingham, and if he had accepted them and taken his works and secret to that city, Sheffield might easily have lost its cutlery trade and much besides.

Baulked of their objective, the cutlers now began a determined attempt to steal Huntsman's secret from him. There is a famous legend that one night a tramp stopped at the Huntsman works, when the cold was extreme, and begged to be allowed to sleep beside the melting furnaces. The workmen (all sworn to secrecy), taking pity on the poor ragged fellow, allowed him to come in and doze in a corner. He slept with one eye open, and next morning went out with the secret in his possession. He was in reality a competing steel maker of the name of Samuel Walker.

This legend is, however, one of those fanciful tales with no foundation in fact. Huntsman's secret did eventually leak out, and the way of it was apparently this. Hunts-

Fig. 3.—The cottage at Handsworth in which Huntsman made his discovery.

man in 1750 or thereabouts was invited to become a member of the Royal Society, and there was an interview in London between one of his representatives and representatives of the Royal Society. Presumably at this meeting some discussion of Huntsman's credentials would take place, involving a disclosure of his methods. A certain "gentleman of the Temple" (presumably, therefore, a lawyer) was present at the meeting, and when Huntsman, for unknown reasons, rejected the offer of membership, this person was nettled. He therefore felt it his duty to reveal his information to a gold-beater named, possibly, Waller. Waller started making steel for the razor trade, but failed. Next, he tried to sell his information. Birmingham would not buy, but the Walkers of Sheffield wormed the secret out of him, gave him a little money and packed him back to London. Knowing much more about steel than he, they were able to make the new steel successfully and sell it cheaper than their informant.

Move to Attercliffe

In spite of his now having to reckon with competition, Huntsman produced a steel which was so much better than that made by the same process elsewhere, and had, moreover, so great a reputation, that he experienced no decline in demand, but only an increase. In consequence, he transferred his works to another outlying village in the Sheffield district, known as Attercliffe (now an industrial district of the city), so that he could enlarge his operations. This was in 1770. The illustration Fig. 3 shows the cottage at Handsworth in which Huntsman first made his discovery. It is taken from an old water-colour sketch of uncertain date, in a book entitled "Doings in Handsworth Woodhouse, 1876–1899" by W. J. LeTall. The painting has been gummed on to the fly-leaf, presumably by the author, and my thanks are due to Mr. G. Milner of Sheffield for the loan of the book.

The fourth illustration shows a couple of the old Huntsman steel-converting furnaces at Worksop Road, one of which was allowed to fall into disuse as recently as 50 years ago. The exact site of Huntsman's original works in Attercliffe is known, but it is completely covered by modern buildings, and unfortunately what few relics remained have been allowed to disappear.

Huntsman lived for another six years, dying in 1776, intestate. He was buried in the yard of Attercliffe Chapel, Hill Top, Attercliffe, Sheffield, and his grave,

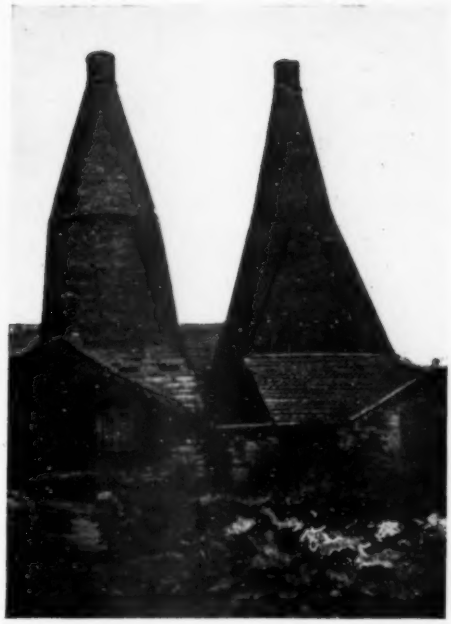


Fig. 4.—Two old Huntsman steel furnaces at Worksop Road.

illustrated in Fig. 5, constitutes the family vault of the earlier members of the Huntsman family. On the left-hand stone inside the railings is the following inscription: "Here lieth the body of Elizth. the Wife of Benjamin Huntsman who departed this life November 3 1760 Aged 54 years. Also Benjamin Son of Willim. and Mary Huntsman who departed this life Novebr. 9th 1765 Aged 6 weeks. Also Mary Wife of William Huntsman who departed this life May 3rd 1774 Aged 41 years. Also John Son of Willim. & Mary Huntsman who departed this life May 12th 1774 Aged 1 month. Also the above-named Benjn Huntsman, died 21st of June, 1776. Aged 72 Years."

Export Trade

It is believed that he was succeeded in the management of his business by his son, William, but it appears that the works were now carried on at an unduly low margin of profit, if not at a positive loss. In 1809 William Huntsman died, leaving only £1,500 as compared to the enormous sums left by the Walkers. It was not until Francis Huntsman (1803–79) took over the management that the business succeeded: it is still actively carried on in Attercliffe. Some of the records of the firm show that between 1791 and 1814, Huntsman was shipping regular consignments of steel to France, Germany, Russia, Austria and Switzerland. When Napoleon issued his Berlin Decrees in 1806, prohibiting all trade between Britain and the Continent, Huntsman still carried on and shipped his steel to Heligoland, whence, as opportunity offered, it was taken to Hamburg and up the Elbe to the interior.

Obviously, Huntsman was well up in the metallurgical knowledge of his period, and may have had some acquaintance with chemistry, of which, however, there is no proof. He had considerable mechanical knowledge and skill. In character he is said to have been eccentric and to have disliked advertisement.

Fig. 5.—Huntsman's grave in Attercliffe old burial ground.

The exact character of his process is obscured to some extent by the secrecy with which he surrounded it, but it undoubtedly consisted in melting blister steel and scraps of shear steel in crucibles at a great heat in a coke furnace. His greatest difficulty appears to have been in finding a clay that would withstand the intense heat for a period of some hours. He overcame the difficulty, it is believed, by mixing local earths (probably ganister and wheel swarf) with clay bought from firms in Stourbridge (of which there is said to be a record). This clay was carried in barrels by wagon to Sheffield. The blister and shear steel used in the process were bought from steel converters in the neighbourhood. Huntsman is also said to have produced large quantities of cast steel wire made for him by Robert Cocker of Hathersage, a wire-drawer.

Huntsman left no will, no portrait and no specimen of his handwriting, but it is possible that research may yet yield further details of this remarkable man and his family.

Production of Heavy Steel Castings

AT a recent meeting of the Newcastle upon Tyne Branch of the Institute of British Foundrymen, Mr. S. Taylor, of the English Steel Corporation, Ltd., presented a paper on the above subject. This was followed by a film dealing with the production of Britain's heaviest steel casting.

Mr. Taylor, who was introduced by the Branch President, Mr. C. W. Stewart, referred to the development in the size of rolling mills and forging and extrusion presses to meet modern requirements, which has created a demand for larger and heavier steel castings. Prior to the war, the largest steel castings made in the foundry with which he is associated weighed about 120 tons, but now the foundry has been enlarged and modernised to facilitate the making of castings of the order of 200 tons in weight. As a result of this development, what are regarded as the largest and heaviest steel castings ever made within the British Commonwealth have been produced—press castings each having a delivered weight of 185 tons.

The making of large castings of whatever shape, size, or structure, always presents a variety of difficulties. Design, feeding, easing, contraction, and many other factors must be considered before a start can be made to construct the pattern. Mr. Taylor directed attention particularly to the successful production of the casting for a 185-ton crosshead beam, the overall dimensions of which were 26 ft. 6 in. long, 13 ft. 6 in. deep, and 8 ft. 6 in. wide, and discussed some of the problems involved.

On the question of contraction, it was decided, as a result of experience, to make an allowance of 1 in 80 on outside dimensions, but for internal cores, $\frac{1}{16}$ in. per ft. short of 1 in 80 was allowed on all lengths and widths, the depth being kept to size. Feeder heads were placed over the heaviest sections, and it was decided to use ten, each 26 in. diameter and 42 in. high. The pouring and running of the casting had also to be considered in the initial stages, and it was decided to run the steel down launders to each end of the mould and through a down runner into the centre of the mould. For this purpose three ladles, each of approximately 70-tons capacity, were used, the centre ladle being fixed on a stand and the end ladles carried by overhead cranes.

The mould was made in a steel-lined pit, the face of the mould to a thickness of approximately 4 in. consisting of "compo" backed up with old moulding sand. The "compo" is a very coarse-grained material made from crushed chamotte (a calcined bauxite high in alumina) and firebricks milled and bonded with 10% of fireclay, with about 10% of moisture. When the pattern was withdrawn, the mould face was painted and finished with chamotte paint to provide a smooth surface. The drying of the mould was carried out for three weeks continuously.

The cores were adequately reinforced with iron grids and the faces were made up with approximately 3 in. of "compo," coarse ashes being used in the centres of them. The main centre core, weighing about 20 tons, was made in two pieces for convenience in drying. Facilities were provided not only for lifting the main core, but for holding it down during the time of casting.

When the mould was completed, closed and secured, the pouring was commenced from the centre, and a few minutes later the two end ladles were opened up. Pouring continued at the rate of about 11 tons/min., the whole casting operation taking 19 mins., during which time 206 tons of liquid steel were cast. When the ladles were emptied the level of steel in the feeder heads was about 32 in. These were repeatedly fed with electric-arc melted steel, and chopped straw was used to cover the heads. At a later stage in the feeding, 1¼ cwt. of a proprietary exothermic material was fed into each head: the whole feeding operation occupied about seven hours.

After allowing it to cool off for about three weeks and roughly cleaning the surface, the casting was transported to a pit-type annealing furnace for heat-treatment, the annealing and cooling cycle taking approximately three weeks, after which the casting was finally cleaned. On receiving its dimensional check, it was gratifying to find that the contraction allowances had worked out to within a fair limit, and all surfaces to be machined were able to be finished to the drawing dimensions.

The film which followed enabled Mr. Taylor to indicate more clearly some of the problems involved in the making of the crosshead casting and to emphasise reasons for decisions made in procedure.

Materials for High Temperature Service

Increasing Interest in Boride–Base Products

THE properties required for a high temperature material are high tensile strength, low creep, high stress-to-rupture strength, good thermal shock resistance, low oxidation and the highest possible impact resistance to mechanical shock. Two classes of materials are being developed to meet these requirements: the super-alloy metals, which are ductile and impact resistant but lose strength at high temperatures; and ceramics, which have strength at high temperatures, but are brittle and thermal shock sensitive.

It seemed likely that by combining these two classes of materials a satisfactory solution would be obtained, but binding ceramic particles together with a metallic medium presents many problems which have been encountered in their development for use in engines operating at over 850° C., the present temperature limit for the super-alloys. The property which is preventing the wide application of ceramics with a metallic binder is the impact strength at room and elevated temperatures. The best of these materials show impact resistances only 20% of that of some of the super-alloys.

New Developments

The materials combining the two classes which are of greatest interest are titanium carbide with nickel or cobalt binder, or with nickel alloys with chromium, molybdenum, or aluminium. A more recent development are boride-base materials, with or without the addition of materials such as chromium or nickel, using zirconium boride, chromium boride and molybdenum boride as the refractory components; silicide materials on the basis of chromium or molybdenum disilicide; and aluminium oxide and chromium materials. Some of the advances in this field are discussed by Steinitz in a paper presented at the recent semi-annual meeting of the American Rocket Society.

New refractory hard materials, having a boride base and possessing characteristics intermediate between those of a metal and a ceramic, are described by Everhart[1], and are claimed to have excellent high temperature properties and corrosion and wear resistance. He states that these materials can be polished to a high lustre and their electrical and thermal conductivities are within the range of pure metals. Furthermore, their temperature coefficients of resistivity at room temperature are positive. The high melting points (up to 5,000° F.) and refractoriness of these materials, combined with their other properties, provide some justification for calling them "refractory hard metals", their actual status remains to be determined.

The commercial borides are made by powder metallurgy processes similar to those used in producing the cemented carbides, but there is a distinct difference in the product obtained after completing the sintering operation. In general, the borides react with metallic binders at elevated temperatures, and ternary and quaternary compound formation occurs. Experience with cemented carbides, therefore, does not provide a direct basis for comparison in evaluating the boride-base products. These new materials can be divided into four groups: zirconium borides, chromium borides, molybdenum borides, and nickel aluminides.

Zirconium Boride

Originally made by pressing and sintering or hot-pressing the pure boride, zirconium boride material has been improved greatly by incorporating a binder phase, and the sintered product is a mixture of the borides of zirconium and a binder. It has a high melting point and good high temperature mechanical properties, although it is not so resistant to oxidation in air at high temperatures as some of the other borides. The material is hard, but brittle in comparison with metals, particularly at room temperature. At elevated temperatures the brittleness is considerably reduced.

It shows excellent resistance to nitric acid, to hydrochloric acid, and to a number of molten materials, including aluminium, copper, tin, magnesium, and the fluorides. Resistance to attack by hydrogen peroxide and to molten silicon and brass is good. Molten iron and molten Inconel attack the boride at rates which indicate that zirconium boride is not a suitable material for handling these metals in the liquid state for extended periods of time.

The high melting point of this material makes it attractive for extremely high temperature (over 5,000° F) applications, including high performance burner systems and rocket or jet reaction systems. This boride has the valuable property of not being wetted by non-ferrous metals, including aluminium, brass, zinc, copper, lead, and tin. Taking advantage of this property, applications have been found in a number of systems for the handling of molten metals.

Chromium Boride

There are two series of bonded chromium borides in commercial production. One series is characterised by oxidation resistance at elevated temperatures which is superior to that of zirconium boride. This group has high-temperature strength and hardness, and is less brittle than zirconium boride. The second series was developed to improve the resistance to impact. This group has greatly superior stress-to-rupture properties and better impact properties than the other series.

Corrosion results reported for chromium boride indicate that dilute nitric acid does not attack it, and the material shows excellent resistance to concentrated nitric, hydrochloric, sulphuric, and hydrofluoric acids. Perchloric acid attacks chromium boride slowly, while the compound is rapidly dissolved by fused sodium peroxide and nitrate-carbonate mixtures.

Applications for this material are based on the corrosion and abrasion resistance, particularly, but it has also been suggested for steam and gas turbine blades, valve inserts and seats for internal combustion engines, and discharge nozzles and exhaust tubes for jet engines.

Molybdenum Borides

These materials also have good electrical properties, high hardness, and good wear resistance. Although little information is available on corrosion properties,

1 From *Materials and Methods*, August, 1954, pp. 90-92.

tests have shown that a molybdenum-nickel boride has excellent resistance to dilute sulphuric acid. As a cutting tool material, one molybdenum-nickel boride shows considerable promise; tests on aluminium and brass show this material to compare favourably with high-speed steels and cemented carbide tool materials. Additional work is necessary to determine the proper conditions for its use on other materials.

Nickel Aluminide

The latest of these refractory hard materials to be produced on a commercial scale are nickel-aluminide products. These are materials composed largely of intermetallic nickel-aluminium compounds. Several grades are available. The melting points of these materials are higher than those of either of the metals from which they are formed. Electrical resistivity is in the same range as the borides already mentioned, but the commercial material has high elevated temperature stress-to-rupture properties, combined with better ductility than is usually found in cermets. Its thermal shock resistance and strength at 2,000° F. are excellent. This material is being considered as a logical replacement material for high temperature service. It appears to be particularly suited for applications requiring high strength and good impact resistance at elevated temperatures. At present nickel aluminide is being evaluated for stator blades or guide vanes in jet engines.

Nut-Making from Round Bar

Some Details of Swiss Practice in a Keenly-Competitive Industry

AN advantage claimed for the hot forming of nuts from round bar, as compared with the method using flat bar stock the width and thickness of the finished nut, is a marked reduction in the volume of waste. This is stated to be of the order of 8–10% with round bar and 33–35% with flat bar stock, which is a matter of considerable importance in such a keenly competitive trade as the standard bolt and nut industry, in which material costs are a more important factor than in the case of products involving a larger number of machining operations.

Fig. 2.—The four stages in the production of hot formed nuts ready for tapping.

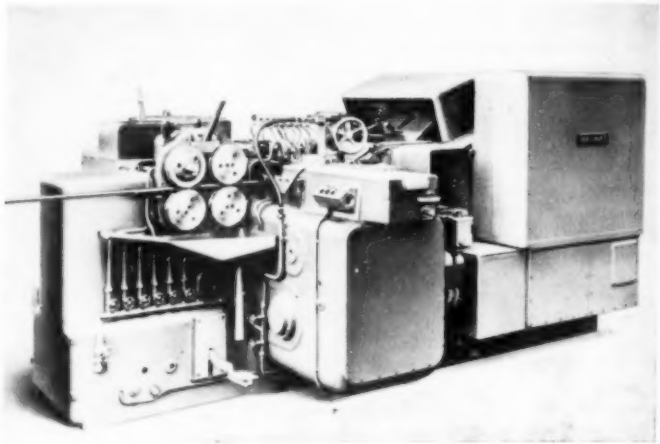
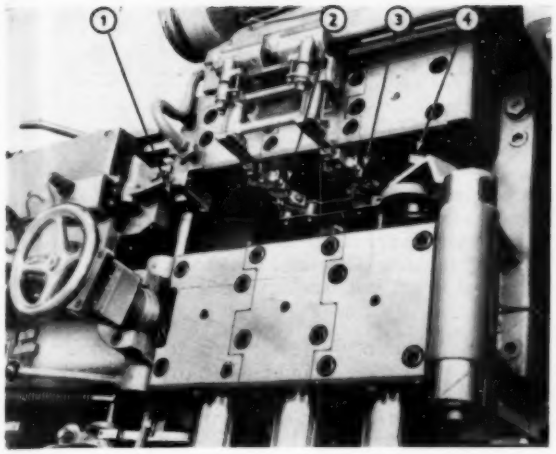


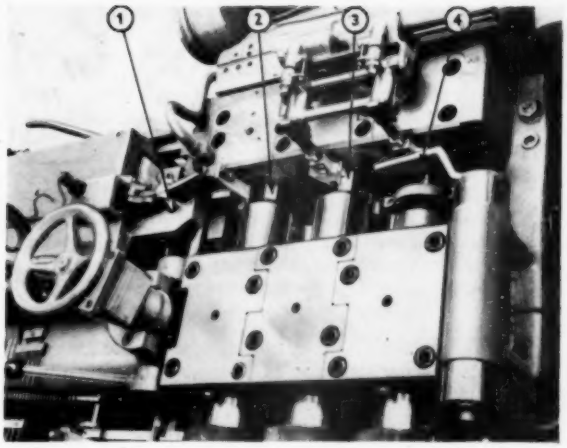
Fig. 1.—Automatic hot nut press.

Fig. 1 shows an automatic hot nut press which has been developed in Switzerland by the firm of F. B. Hatebur, of Basle, for working on round bar and having a high rate of production, this being in the region of 90 to 100 pieces per minute in the case of standard $\frac{3}{4}$-in. nuts. It is a 4-station machine, the sequence of operations from left to right being: (1) feed to stop and cut off; (2) upset and square up blank into rough hexagon shape; (3) pre-form hole from both sides, counter-sink, and chamfer (at this stage trade or other mark may be impressed); and (4) pierce out slug and calibrate hole. The appearance of the material at each stage is shown in Fig. 2.

Operation of the Machine

Detail views of the tooling are shown by the photographs Figs. 3 and 4. The bar is fed to the machine at forging temperature by means of the feed rolls seen in the left of the photograph of the machine, the bar being fed up against a stop, the position of which can be adjusted during operation by a handwheel. Lateral movement of the blank is effected by the transfer fingers shown. On the forward movement of the main ram, the various blanks are brought in front of the appropriate dies and inserted into them by the respective punches, and as the opposing tools contact the blanks the fingers open and withdraw to make way for the punches to enter the dies. During the return stroke of the main ram, as





Figs. 3 (left) and 4 (right).—Views of tooling layout with working stations numbered.

the blanks at the second and third stations are ejected into the transfer fingers, and the bar again fed forward to re-commence the cycle, the finished nut at Station 4 is drawn back by the piercing punch and removed by the stripper plate, the nut blank leaving the machine separated from the waste slug, and completely finished except for the subsequent tapping operation.

The following is the stage in the cycle of operations shown by Fig. 3. At Station 1 the shearing slide has just cut off a blank and carried it over to the first pressing die; at Station 2 the squared-up blank has been ejected into the transfer fingers and carried over to Station 3; at Station 3 the pre-formed blank has been ejected into the transfer fingers and is carried over to Station 4, where the finished nut blank is stripped off and falls down the chute. Fig. 4 shows blanks being worked at each station, as follows: (1) the shearing slide is on its return stroke; (2) a roughly hexagon-shaped squared-up blank is being formed, the transfer fingers having been opened by reciprocal torsion of the tubular shafts; and (4) the waste slug is being punched out; the transfer fingers have been opened, and are about to return to Station 3 to pick up the next pre-formed blank when ejected.

A number of safety devices are incorporated in the machine to obviate risk of overloading any of the mechanism as would happen, for instance, if a pre-formed blank were drawn back by the pre-forming punch, or in the event of any failure in the electricity or compressed-air supplies, in all of which eventualities the machine is stopped immediately. The drive is by 50-h.p. electric motor, and the machine in operation requires a supply of compressed air at 60–100 lb./sq. in. for the operation of the electro-pneumatic clutch and brake, the consumption being from 350 to 450 cu. ft./hr. The capacity of the machine illustrated is from $\frac{3}{4}$ in. to $1\frac{1}{4}$ in. nuts, the production being in accordance with Table I.

TABLE I.—PRODUCTION DETAILS

	Size of Nut				
	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.	$1\frac{1}{8}$ in.	$1\frac{1}{4}$ in.
Production (pieces/min.) ..	90–100	80–100	75–100	70–90	70–90
Heated Stock Required (lb. min.)	23	28	40	50	66
Size of Waste Slug					
Diameter (mm.)..	16·5	19·5	22·5	25·1	28·3
Thickness (mm.)	3·5	4·0	4·5	5·0	6·0

The machine requires to be run at these rates of production as far as circumstances permit, as a slow-running press has the disadvantage that the contact time of the tools with the heated material is longer, resulting in a proportionately reduced working life of the tools.

Davy-United Press for France

An order to build a 6,000-ton hydraulic wheel forging press has recently been placed with Davy and United Engineering Co. Ltd., of Sheffield, by the French steel firm Société Anonyme des Acieries et Forges de Firminy. The press will be similar to one of the same power built by Davy-United for Steel Peech and Tozer some six years ago. It will be installed in the French firm's works at Malo-les-Bains, two or three miles north of Dunkirk, and will be supplied along with two 600-h.p. hydraulic pumps, 400-gallon air hydraulic accumulator, hydraulic intensifier and other ancillary equipment. S.A. des Acieries et Forges de Firminy are now embarking on the manufacture of large type wheels for railway rolling stock. The new press will be able to forge solid railway wheels up to 45-in. diameter and will represent the French company's first essay in producing wheels of "monobloc" form—meaning that no separate tyre is required—in anything approaching that size. It is expected that the greater part of manufacture will be carried out in the works of Davy-United's Glasgow subsidiary, Duncan Stewart and Co. Ltd.

Sulphuric Acid Plant

The Power-Gas Corporation Ltd. of Stockton-on-Tees has recently been awarded a contract for the reconstruction of an existing sulphuric acid plant at the Flixborough Works of Nitrogen Fertilisers Ltd. The new equipment will be built to the designs of Chemiebau Dr. A. Zieren G.m.b.H., and will comprise a converter unit with a capacity of 140 tons per day of monohydrate, an acid separator, waste heat boiler and ancillary equipment. The programme for installation of the equipment has been carefully planned to reduce to a minimum the inconvenience of shutting down the existing plant.

Deterioration of Motor-Cars During Shipment Overseas

A paper on the deterioration of motor-cars during shipment overseas was read by Mr. E. A. Shipley, of Morris Motors, Ltd., at a recent meeting of the North-East Coast Institution of Engineers and Shipbuilders. The paper dealt with mould attack on upholstery, blistering of paint-work, and corrosion of sub-assemblies and components, but in this abridged version attention is confined to the last two aspects.

DETERIORATION in motor-cars during shipment differs considerably from that occurring during service, since the effects of general " wear and tear " are not encountered, neither are sunlight and dust, which play an important part in the breakdown of automobile paint finishes. Nevertheless, a voyage of five or six weeks' duration aboard ship is not without hazard.

Condensation of moisture (i.e. cargo or ship's sweat) and relatively high humidities, associated with perhaps rapidly changing temperatures of up to 90° F., are conditions which can be encountered during a voyage to Australia, and it is these conditions that are known to produce the deterioration which it has been the makers' aim to prevent since vehicles have been transported overseas in the large proportions to which we have become accustomed in the post-war years.

Motor-cars are exported in two main forms; " built-up " (i.e., complete vehicles) and " C.K.D." (comprising individual components and sub-assemblies). Before considering the efforts which have been made to overcome troubles associated with built-up vehicles, consideration will be given to the methods used for the C.K.D. shipment.

" C.K.D." Components and Assemblies

These problems are all connected with the corrosion of metal parts or sub-assemblies, which, of course, can be seriously affected by the highly humid conditions likely to occur during shipment. It has been necessary to provide these mainly ferrous items with some form of temporary protection, and the initial investigations were related to the evaluation and choice of the most suitable types of protectives to be applied.

Although it may seem strange that textile trim materials, which, as stated later, can be very seriously affected inside built-up vehicles, are not mentioned here as requiring protection, it should be remembered that in the C.K.D. form they are wrapped and packed closely, the associated air spaces thus being of very low proportion, and the moisture therein too little to cause trouble.

The protection of individual items is relatively simple : solutions of lanoline, resin, sulphonated oils or mixtures of these, are used to produce a relatively thin but highly protective film on fully machined parts, which are then wrapped in waxed papers and cartonned. Occasionally, thick strippable coatings of ethyl cellulose are employed, which not only provide excellent protection against corrosion but also have good resistance to mechanical damage, and thus obviate the need for subsequent wrappings or cartonning. There are many such proprietary preservatives available, and well over 100 compounds were compared by means of salt spray, humidity and atmospheric exposure tests in order that the best protection should be provided under all conditions.

Sub-assemblies such as engine units, gear-box units, rear axles, front and rear hub assemblies, and electrical items, presented a somewhat greater problem, since initially it was not fully appreciated that methods of protection suitable for storage in this country would not successfully withstand conditions which occur during shipment or during storage in tropical areas. Two examples will serve to illustrate this point.

During the war, and for some years following, it was customary to protect the cylinder bores of engine units by spraying internally with a solution of lanoline in white spirit or solvent naphtha. Such treatment was soon proved to be unsuitable by reports arriving from Australia and India indicating that severe rusting had brought about the complete seizure of the engine during the outward voyage. Laboratory experiments proved that the use of this type of rust preventative was not suitable for protection under shipping conditions, and alternative methods had to be sought. Extensive investigations, which involved the testing of complete engine units in a humidity cabinet, proved that an oil-based or non-solvent-containing preservative was desirable in this particular case, and protective compounds of this nature were adopted as standard practice.

Brake-drum assemblies presented peculiar difficulties : the braking surfaces, which are lapped to a high finish, could not be treated with the customary preservatives, as these would contaminate the brake linings. The answer to this problem was finally reached by the use of one of a new range of chemicals known as vapour phase inhibitors. This chemical is introduced into the brake drum unit as a solution in industrial spirits or in powder form, it being necessary to seal all orifices with adhesive tape to prevent egress of the protective vapour which is given off from the solid material.

A further problem associated with the C.K.D. form of exportation is " filiform " corrosion, a peculiar form of rusting commonly seen on the lacquered tops of jam jars, etc. This form of corrosion, which usually takes place beneath a paint or lacquer film, in atmospheres of high humidity, has occurred from time to time on body panels that have been shipped in the primed condition. Extensive damage of this nature renders the panels unsuitable for finishing until the damaged areas have been rectified by paint stripping and derusting. " Filiform " corrosion can be entirely prevented by pre-treatment of the steel panels by one of the well-known proprietary phosphating processes, but in the case of C.K.D. body panels such a procedure is unsuitable, since the phosphate coating interferes with the spot-welding

which is subsequently used to fabricate the body. Once more, the use of a vapour-phase inhibitor proved the answer and body panels are now sent " in the white " (i.e., not painted) in cases lined with waterproof paper coated with the inhibitor, the treated paper also being placed in between sets of panels.

Built-Up Vehicles

The need for an investigation into the deterioration during shipment of built-up vehicles became obvious during the big export drive in the years 1949–51, when many motor-cars arriving in distant countries, mainly Australasia, were found to be affected by mould growth on the upholstery, and blistering of the exterior paint finish. Such deterioration was somewhat surprising, since many of the vessels used for the purpose had been built during the post-war period, and were equipped with more advanced types of hold-conditioning apparatus than their pre-war counterparts, in whose day it has been said such trouble was rarely encountered, although admittedly a smaller number of cars was exported.

Warm, damp, and possibly stagnant atmospheres can have a disastrous effect on automobile paint finishes. Even the best paint films are permeable to water vapour, and if, due to very high atmospheric humidity, or even condensation on the surface, penetration does occur, it may set up forces sufficient to weaken the adhesion between the various coats or the adhesion of the whole paint structure to the underlying metal. As a result, blisters may form, and in numerous cases deterioration has been so severe that vehicles have had to be cleaned down to the bare metal and completely resprayed.

Early Work

The initial experiments carried out at the end of 1949 concerned a number of built-up cars packed in standard wooden boxes. Two methods of treatment were used :—

(1) Enclosure of the vehicle by means of a thin plastic film (polythene), which was completely sealed to prevent ingress of moisture, and which contained a dessicant (silica gel) to absorb the enclosed moisture. This treatment was designed to protect both interior and exterior of the vehicles.

(2) Partial cocooning of the paint-work by means of special plastic materials, similar to those used for the protection of warships and aeroplanes stored by the Ministry. This treatment was used only to protect the paint-work, not to seal off the vehicle completely, as in (1).

The results of this work indicated that enclosure in a plastic film was a completely successful method of protection, but was so expensive that it was considered impracticable for large-scale packing. Cocooning of the paint-work was also a failure, as the plastic solutions applied at the time seriously affected the automobile paint finishes, whether cellulose or synthetic.

Further Investigations

It was soon realised that further work had to be carried out in order to find less expensive methods of protection. A number of factors were involved, and, in order to throw light on these, a series of investigations was begun, as follows :—

(1) Determination of conditions prevailing in the holds of vessels during long-period voyages.

(2) Laboratory tests to determine the cause of paint breakdown, and possible means of prevention.

(3) Survey of vehicles delivered to Australia through a specific period of time, with an assessment of the cost of rectification of damage.

Conditions During Shipment

It was obvious that, notwithstanding the fact that quite a few ships were equipped with modern air-conditioning apparatus, very adverse conditions were developing inside holds during the voyage. In order to determine the conditions prevailing inside individual cars, a recording instrument was developed, in which the dials of a thermometer and a hair hygrometer were photographed automatically every hour. The temperatures and dew points of the deck atmosphere and the general hold atmosphere were determined by the ship's officers. These records showed that relative humidities of 80% or more are regularly attained and maintained inside packed cars during the voyage to Australia, and that, associated with these relative humidities, temperatures of 75° F. or more are frequently reached. The relationship between the deck and hold temperatures and humidities, and the presence or absence of ventilation, are important factors in determining whether or not condensation occurs. The records suggest that insulated holds are less suitable than non-insulated holds, for the transportation of general cargo such as cars, since a longer time is required to raise the cargo temperature.

Survey of Extent of Damage

In order to obtain some idea of the extent of damage caused by mildew and paint blistering, a survey was made between June 1951 and March 1952 of the out-turn condition of all cased and uncased vehicles sent to Australia during that period. This was not only to provide an indication of the cost of rectification, but also to act as a guide on how to make a further attack on the problem

The survey covered 130 different shipments, comprising a total of 8,843 cars, 6,863 of which were sent in the boxed condition, the remainder being uncrated 'tween deck cargo. The results showed that boxed vehicles despatched from this country to Australia between November and February, inclusive, are more liable to damage than at any other period of the year ; 10–20% of the cars were damaged by blistering during this period as compared with 12% over the whole survey period. Between sailing dates April and June, inclusive, paint blistering was almost negligible. Paint blistering on 'tween-deck cars was more erratic and not related to the sailing date in any way. The average cost of repairing the damage due to gross paint blistering was £45 per car affected.

Laboratory Tests

In addition to the field tests previously described, considerable work was carried out in the laboratory relating to deterioration of the paint-work. Since the type of failure most concerned is that due to blistering, reference will be made only to investigations made to determine why paint films fail in this manner, and the possible means for preventing such failures.

The initial work comprised subjection of steel panels, fully painted with the systems used on the cars, to the high humidity conditions prevailing in a humidity cabinet. Such conditions could be controlled fairly accurately and the following daily cycles were used :—

Nine hours at 120° F. with 100% relative humidity, followed by 15 hours cooling to room temperature. Severe condensation was promoted on the test panels during the early stages of the heating cycle by supporting them on fairly thick wooden blocks, which, of course, tended to keep the painted surfaces cool while the surrounding atmosphere became warm and completely saturated with moisture. This effect is, of course, analogous to the ventilation of a hold carrying a comparatively cool cargo with a relatively warm atmosphere whose dew point is above the temperature of the cargo.

A subsequent test, in which conditions can be far more accurately controlled, comprises immersion of the test panels in a bath of agitated distilled water at 100° F. This test has been found to give more reproducible results than the humidity test, and is now part of the standard test programme to which all production finishes are subjected at regular intervals. The test in itself is limited to 500 hours complete immersion, although it is not expected that even satisfactory paint systems will withstand the full length of test without breakdown, but it has been established that an inferior system will break down within the first 150 hours of the test and the extent of breakdown will become very severe upon completion of the test. Satisfactory systems will show only slight breakdown at the end of 500 hours.

The type of blistering which is more commonly brought about by adverse hold conditions is that known as "water blistering." Examination of films which have failed in this manner indicates that the blisters have occurred in the finishing colour coats, the underlying primer surface or filler coats remaining intact. This type of breakdown can be brought about by the use of undercoats have water-soluble constituents ; the mechanism of blistering in this case is penetration of moisture vapour through the colour coats (which act as a semi-permeable membrane) by the phenomenon known as osmotic pressure, greater penetration of moisture being obtained with high solubility of the pigment of the undercoat system. Considerable work has been carried out to find the most suitable primer surfaces or fillers having the maximum resistance to moisture absorption and low pigment solubility.

In addition to this work, numerous experiments were undertaken to find possible means of preventing vapour from reaching the painted surfaces, e.g., coating these surfaces with protective waxes. Even to-day certain manufacturers are still experimenting on these lines. Approximately 16 different experimental materials have been investigated : each material was applied as a solution in a solvent innocuous to paint finishes, the coated specimens then being subjected to standard humidity tests. While a number of these coatings completely prevented blistering, it was found that subsequent removal of the protective film left a paint finish which, unfortunately, was unduly susceptible to breakdown under service conditions, and for this reason it has not been possible to adopt this method of preventing paint blistering . Work of this nature is still being carried out although it seems doubtful whether any protective coating will be found which does not have an injurious effect on the underlying paint film.

Conclusions

Considerable effort has been made on the car manufacturers' part to overcome the problems of deterioration associated with the shipment of vehicles. Corrosion of metal components and assemblies is now virtually non-existent due to the use of effective corrosion preventives and inhibitors, but the damage of paint-work by blistering, a serious and costly business, cannot be entirely eliminated by efforts on the part of the car manufacturer or paint maker. It is, therefore, obvious that more adequate knowledge and control of conditions prevailing inside the holds of vessels during long period voyages will be necessary before these problems can be completely solved. It has been shown that temperatures provided by ships' instruments located in holds do not always give a true indication of the temperatures of the actual cargo, and, as is well known, an error of 5° in the recorded temperature can easily mean the difference between a satisfactory and disastrous out-turn.

It is also felt that there is need for the greater use of mechanical ventilation, possibly together with air-drying equipment, although it may be that mechanical ventilation alone, if properly used in conjunction with accurate records of hold cargo temperatures and dew points of air entering and leaving the holds, could go a long way towards the elimination of those conditions which give so much trouble.

Welding Demonstrations

REFERENCE was made in the December, 1954 issue to the adaptation of the Argonaut process to the welding of mild steel. The process has been used for the welding of aluminium alloys and stainless steel for some time, but a number of difficulties were encountered in applying it to mild steel. These have now been overcome and the process was on show to the public for the first time last month, when a series of demonstrations was given at the British Oxygen Company's new welding school at Walkden, Manchester. This school is associated with the new works which will ultimately replace the Trafford Park works.

In addition, two other first time showings took place at the demonstrations. The first was a new Argonare equipment for machine welding with an automatic rod feed, and the second a new miniature pencil torch specially developed for making joints in positions which are difficult of access, such as occur in the manufacture of jet engines.

Visitors were also able to see a colour film which included several revealing slow motion sequences showing clearly how effective an argon gas shield can be in helping to achieve a strong, clean weld at high speeds.

Turbo-Blower for Iron Works

THE General Electric Co., Ltd., announces that its Fraser and Chalmers Engineering Works, Erith, Kent, has been awarded a contract for a turbo-blower to be installed at the Clyde Iron Works, Tolcross, Glasgow, of Colvilles, Ltd. The output of the machine is to be 75,000 cu. ft./min. of dry air at 60° F., at a delivery pressure of 25 lb./sq. in. The turbine—a multi-stage, single casing, high-pressure machine—will be supplied with steam at 270 lb./sq. in. gauge at a total temperature of 750° F., and will drive the four-stage centrifugal blower at 2,750 r.p.m. The control of the machine will be by a constant volume anti-surge regulator of the Ascania type. The contract includes surface condensing plant and auxiliaries.

Mobile Forging Manipulator

Hydraulically Operated Unit of 2,000 lb. Capacity

THE HEAD WRIGHTSON MACHINE CO., LTD., have recently completed at their Middlesbrough Works the first 2,000 lb. capacity forging manipulator built under the license arrangements with Salem-Brosius, Inc., of Pittsburgh, U.S.A. The manipulator—the smallest of the Brosius range, which extends to a capacity of 20,000 lb.—is designed to charge billets into a heating furnace, transport the heated billets from the furnace to the forging press or hammer, and manipulate the forging throughout the entire hot working operation.

The fabricated steel frame is mounted on three wheels —two at the front and a single driving and steering wheel at the rear. The front of the machine is supported by heavy coil springs, which absorb the shock of the forging blow. The floor speed of 250 ft./min. is obtained by means of an electric motor driving through gearing onto the rear wheel. An electro-magnetic brake is attached to this motor, and is automatically applied when the motor is stopped. By braking the machine at the source of motive power, greater sensitivity of control is obtained. The manipulator can turn on its own wheelbase, thus serving furnaces, presses or hammers in any area that allows clearance for the machine and its load. An indicator at the operator's feet shows the direction in which the rear wheel is turned, so that he knows which way the manipulator will move on starting the drive.

All other motions, including steering, are hydraulically operated, the power being derived from a Hele-Shaw variable volume pump which is driven by a 10 h.p. D.C. motor. A 220 volt supply is fed to a slip-ring assembly mounted on a mast at the rear of the machine, via a flexible cable and take-up reel, the latter being mounted on the shop structure. Similar units deriving their primary power from a self-contained diesel engine are now being built. The work holding unit is raised and lowered by a hydraulic cylinder acting through a linkage, which results in a parallelogram type of motion. A second cylinder is used for tilting downwards, so that the tongs can pick up material from the ground.

The jaws fitted to this particular machine were especially designed to handle pieces of a large cross-sectional area : material from 6 in. square to 24 in. square can be handled. Various types of jaw can be fitted to the machine, and can be designed to suit the type of material to be handled in each individual case. The tongs themselves are opened and closed on the work hydraulically, and any possibility of dropping a load in the event of failure in the hydraulic system is eliminated by hydraulic check valves. Rotation of the tongs at 10 r.p.m. is by means of a hydraulic motor driving through a Heliocentric gear reducer. This motion can be continuous or intermittent in either direction, the continuous rotation permitting the smooth gradual reduction of forging stock under the hammer.

Perhaps the most important feature of the motion is the introduction of a lateral movement to the work holder mechanism. This makes it possible to position the work on the furnace hearth, on the anvil, or in swages, without having to move the machine. The lateral movement on the manipulator just supplied is 6 in. on either side of the centre line, but up to 12 in. movement each side can be made available.

The controls are grouped conveniently round the operator, and both electrical and hydraulic controls are fitted with a " dead man handle " device. From his comfortable seat, the operator has an excellent view of the workhead.

The 2,000 lb. machine has an overall length of 18 ft., a width of 9 ft. 3 in., and a weight of about 10 tons. The lowest position of the tongs with the work-holding unit horizontal is 2 ft. $1\frac{3}{8}$ in. above floor level, and the load can be raised the maximum 2 ft. $3\frac{5}{8}$ in. in 13 seconds. To open the jaws from the minimum of 6 in. square to the maximum of 24 in. square takes 11 seconds, whilst the full 12 in. lateral movement of the work holding unit can be effected in 5 seconds.

It is claimed that economies can be effected in several directions by using manipulators of this type. Initial equipment costs and maintenance costs are said to be reduced, and the fact that one man takes the place of work-handling crews normally needed for charging and discharging furnaces, manipulating stock under the press or hammer, and transporting it to the next process, leads to substantial savings with labour costs at their present high rate. Amongst the orders now in hand are machines for delivery to India and Italy.

Ferritic Steels at Low Temperatures

Paper to Institute of Refrigeration

In a paper recently delivered to the Institute of Refrigeration*, Dr. N. P. Allen showed how heat treatment can lower the temperature at which embrittlement of iron and steel occurs and the effect of the addition of various elements. In his discussion on the behaviour of ferritic materials at low temperatures, he paid particular attention to some features of the work carried out over the past few years in the Metallurgy Division of the National Physical Laboratory.

There is much interest at the present time in the properties of ferritic steels at low temperatures, or under conditions where notches are present in a structure. This is mainly because of the extended use of low temperatures in chemical engineering, of the use of aeronautical and military equipment at moderately low temperatures, and of the failures of welded structures, particularly in cold weather. The cheapness and availability of ferritic steels are such that these materials have to be used as extensively as possible. A knowledge of the limitations of these materials and of the factors that influence their properties is, therefore, important to engineers who have to design equipment to withstand particular combinations of conditions of stress and low temperatures.

High Purity Iron

Dr. Allen described the properties of high-purity iron, the modifications to the behaviour of iron produced by certain impurities and alloying elements, and the effects of the two elements, carbon and manganese, which are present in all steels, ending with a discussion of the properties attainable in some hardened and tempered commercial steels.

Pure polycrystalline iron shows a brittle behaviour in a notched bar test at about −15° C., but does not become brittle in plain tension until much lower temperatures of about −150° C. are reached. A single crystal of iron at −196° C. is either ductile or brittle according to the direction of the stress. Phosphorus has a detrimental effect on the properties of iron because it raises the temperature of transition from a tough to a brittle fracture. Some detailed results are also given to show the adverse effect of phosphorus in a heat-treated 1½% manganese-molybdenum steel. The importance of hardening fully prior to tempering is brought out by these results.

Effect of Other Elements

The behaviour of polycrystalline material is further complicated by the fact that some elements, e.g., oxygen, nitrogen or phosphorus in iron, reduce the brittle fracture stress by weakening the grain boundaries to such an extent that brittle fractures may take place partly or wholly along the grain boundaries. The sensitivity of this effect to heat-treatment is illustrated by the remarkable grain-boundary weakness that can be developed in iron-nitrogen alloys.

Steel differs from pure iron principally in containing carbon and manganese, and the effects of carbon and manganese separately and together on the properties of iron at low temperatures are described. The effect of carbon on iron depends upon the heat-treatment and on the quantity present. When slowly cooled from the austenitic condition, steels of all carbon contents are brittle at −196° C. Steels of very low carbon content (below 0·05%) are much improved both in strength and toughness at low temperatures by being cooled rapidly. Steels containing enough carbon to be hardened are embrittled by this treatment. Excellent properties can be obtained at −196° C. from steels containing 1–2% of manganese and 0·05% of carbon suitably heat-treated.

* "The Mechanical Properties of Ferritic Steels at Low Temperatures" by N. P. Allen, D.Sc.

Applying Insulation to Metallic Surfaces

The Admiralty has for some time now been using a Fibreglass sheeting known as Navyboard for deck and bulkhead insulation on warships. This particular use of a Fibreglass material, and the stud welding procedure adopted for securing the sheeting, will be of interest to builders of commercial ships and, possibly, to manufacturers concerned with other fields of engineering where it is necessary to attach thermal or acoustical insulation to metallic surfaces.

The Fibreglass sheeting employed for warships varies in thickness between ¾ in. and 2 in., and is of a semi-rigid nature, faced on one side with a specially treated puncture-resisting glass cloth. Various methods of fixing the material were considered, including those requiring drilling and bolting or riveting, but the method eventually accepted was that developed by the Stud Welding Organisation of Crompton Parkinson, Ltd., in co-operation with the makers of the insulation, Fibreglass, Ltd.

After cleaning and marking out the surfaces to be covered, $\frac{3}{16}$ in. diameter plain pins, having flat slightly chamfered outer ends, are stud welded to the platework. The insulation is then simply impaled on the pins and finally secured by polythene-capped "Speed Fixes," the latter consisting of perforated spring steel washers having two teeth which with light finger pressure can be pressed over the pins which they then grip tightly.

In addition to the advantages of simplicity, speed, and low cost, with the fixing method described there is no perforation made in the metal structure, therefore precluding the formation of weak spots susceptible to corrosion and mechanical stresses. Protection against corrosion—so important, of course, in marine atmospheres—is still further provided by covering the ends of the pins with polythene-capped "Speed Fixes."

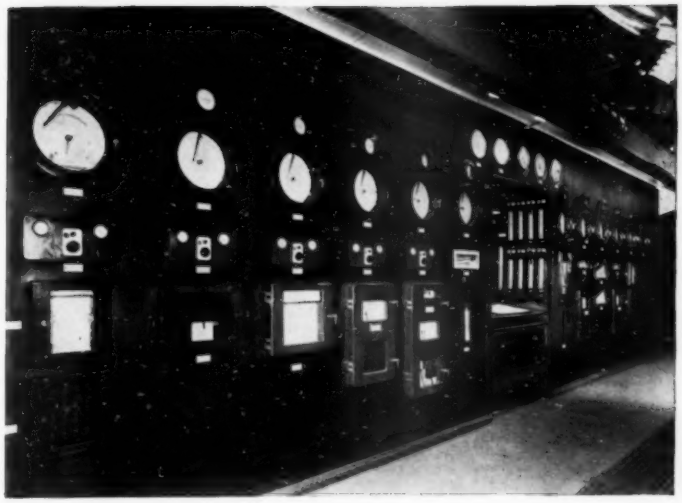
The pins for stud welding may be of either steel or aluminium alloy, according to the nature of the metallic surface to be covered, and the structure should be at least $\frac{1}{16}$ in. thick if it is of steel, and $\frac{1}{8}$ in. thick if it is of aluminium or aluminium alloy.

Aluminium Union Ltd.

Aluminium Union Ltd. announce that Branch Sales Offices have been opened at Gazette Buildings, Corporation Street, Birmingham (Tel.: Central 1446) and at National House, 36, St. Ann Street, Manchester (Tel.: Blackfriars 9772/3). The Birmingham Office is in charge of Mr. W. J. Cadd and the Manchester Office in charge of Mr. A. W. K. Lees.

Automatic Boiler Control at Ironworks

Kent Installation at Skinningrove



RECENT developments at the Skinningrove Iron Co., Ltd., include the addition of a Daniel-Adamson water-tube boiler to their previous two Vickers-Spearing units. All three boilers can operate either on blast-furnace gas or combined gas and pulverised-coal firing. Automatic-control equipment for the new boiler, and the majority of the general instrumentation for all three, was supplied by George Kent, Ltd.

The following description of the control lay-out is applicable to the Daniel-Adamson boiler. The steam pressure is controlled by regulating the amount of blast-furnace gas supplied to the boiler. A Kent pressure recorder/controller measures the final steam pressure, any deviation from a pre-set desired value varying the output air-pressure signal of a Kent Mark 20 pneumatic controller. This output signal is fed into the " remoset " unit of a Kent ring-balance recorder/controller measuring the gas flow to the boiler. The " remoset " adjusts the gas-flow desired-value pointer according to the steam-pressure conditions. A pneumatic control signal from a Mark 20 in this instrument, then actuates a power cylinder regulating a butterfly valve in the gas main. This system maintains steam pressure constant under all conditions of boiler loading.

Efficient combustion is achieved by keeping a constant ratio between gas and air flow. A Mark 24 pneumatic transmitter is installed in the gas-flow meter, and this sends an air pressure, proportional to the gas flow, to a " remoset " bellows in a Kent ring-balance air-flow indicator/controller. The " remoset " positions the desired-value pointer of the instrument through a ratio mechanism, set to the required ratio of gas to air. The output control signal of a Mark 20 in the air-flow indicator/controller then operates the power cyclinders which regulate the speed of the induced-draught fans, at the same time making a corresponding change to the power cylinders which govern the speed of the forced-draught fans, though to a lesser degree owing to the signal passing through a differentiating relay. As the signal dies away, the responsibility for forced-draught control is assumed by a Mark 20 in a Kent furnace-pressure controller dealing with combustion-chamber pressure, until further changes occur in the induced-draught flow.

A Kent Multelec temperature controller is used to regulate the superheated-steam temperature. A Mark 20 operated by the Multelec operates a power cylinder which sets a mixing valve, proportioning superheated and de-superheated steam flows to maintain a constant final steam temperature.

The illustration shows the instrumentation and control panel carrying instruments for all three boilers. The top row of instruments to the left of the central recess, consists of Kent mercurial steam and feed-water recorders and integrators, except for the extreme left-hand one, which is the master steam-pressure recorder/controller. Below these meters are the auto/manual sub-panels for each control instrument, which provides facilities for manual control of the boiler. The remaining four control instruments are mounted below their respective sub-panels.

To the right of the recess is the section carrying Kent mercurial meters for steam and feed-water flow, and ring-balance meters for air and gas flow, for the two earlier boilers.

Bridge Across the Volta

THE Government of the Gold Coast have accepted the tender of Dorman Long (Bridge & Engineering), Ltd., for a single-span steel bridge and approaches across the River Volta at a cost of approximately £750,000.

Situated at Adomi, 2½ miles north of Senchi, the bridge will carry two lanes of traffic on a 22 ft. wide roadway. It will have short reinforced concrete approaches and about 5½ miles of new approach roads which are included in the contract. The river is at present crossed by means of a ferry which handles well over 200 road transport vehicles a day.

The main arch span will be 805 ft. long and 38 ft. wide. The arch ribs will be made of high tensile steel and will have a rise of approximately 173 ft. The total weight of steel involved in the contract is approximately 1,200 tons and the bridge will be completed, ready for traffic, during the early part of 1956.

The Consulting Engineers are Sir William Halcrow & Partners, and Freeman, Fox & Partners, both of London.

Bell Furnaces for Heat Treatment of Silicon Steel

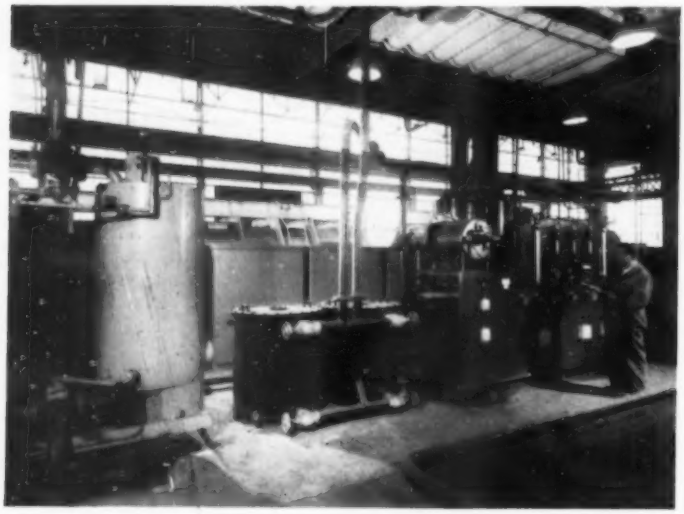
Six-Unit Installation at Wolverhampton

Six Birlec lift-off bell furnaces for the heat treatment of silicon steel sheet. The two hearths for each furnace can be seen.

JOSEPH SANKEY & SONS, LTD., of Wolverhampton, have recently installed, for the heat treatment of silicon steel sheet, six Birlec lift-off bell furnaces in addition to the units already in operation, both of Birlec and their own construction. The silicon steel, which is treated in both flat and coil form, is for eventual use as low-loss electrical transformer sheet.

As is well known, this heat treatment operation involves temperatures of up to about 1,100° C., and special features have, therefore, been incorporated in the furnace design to meet these conditions. The furnace bodies are parabolic in shape, this section providing the maximum constructional strength at heat, and also ensuring the greatest possible degree of temperature uniformity throughout the charge. The heating elements, of nickel-chromium strip and in two zones, are secured to the furnace brickwork by the patented Birlec removable hookpin method, which is of particular advantage in equipment operating at high temperatures, where a comparatively short life may be expected. For renewal, the pins are simply withdrawn and can be replaced without disturbance of the brickwork. Maintenance costs are thereby appreciably reduced and furnace stand-down times kept to the minimum.

Each furnace is supplied with two hearths, enabling the greatest output to be obtained from the heating potential of the equipment. After a charge has reached a sufficiently low temperature in its cooling cycle to prevent oxidation on exposure to air, the furnace bell is transferred to the companion hearth, where it heats up a fresh charge. The first charge is then covered with a sheet metal hood to which a supply of protective atmosphere is maintained. These hoods are rectangular in all sections, conforming to the stacking of the metal sheet on the hearths.



I.C.I. atmosphere generator, comprising a standard cracker with catalyst and regenerative ammonia burner.

The hearths are built up of a plinth of refractory and insulating brickwork on a structural steelwork base. The flanges of the bell engage in the hearth in a continuous trough filled with Cerrobend—a low temperature sealing metal—to ensure that no atmosphere losses occur at this point. Electric heaters are built into the sealing channel to melt this metal. Each furnace is located on its hearth by two guide posts, set at diagonal corners, and each hearth is also provided with a plug box to take the furnace bell socket for the electrical connections.

The non-oxidising furnace atmosphere is obtained from an I.C.I. ammonia gas generator comprising a standard cracker, with catalyst, and a regenerative ammonia burner. To achieve the low dewpoints required, the atmosphere is passed through standard Birlec Lectrodryers, one to each furnace. These dryers work on the principle

of adsorption by activated alumina, a granular substance with the ability to take up moisture from gases passed through it, and also to release it when heated, without deterioration of its drying properties. As in this installation, the dryers are usually of the "dual adsorber" design, so that, whilst one bed of alumina is drying the gas, the other is being reactivated by heat. Continual drying is thus obtained, the duties of the beds being changed over at about eight hour intervals.

As far as electrical installation is concerned, the six furnaces are divided into two groups of three. The supply to each group is fed to a 550-kVA. H.T. transformer of E.C.C. manufacture, providing the furnaces with power at 210 volts, 2 phase. The switchgear, supplied by Contactor Switchgear, Ltd., is double-pole with overload drives and timelags for each phase.

Each furnace is rated at 180 kW. The control instruments are of Kent manufacture, each zone being provided with a combined indicating control and programme regulator, calibrated 0/1,200° C. The instruments for each group of furnace are mounted on a common Sindanyo panel, set in line with the electrical gear.

Aluminium Subway Cars for Canada

ONE of the most advanced examples of urban transport practice is provided by four aluminium alloy cars that have recently been completed by a British firm for Canada's first underground railway system, opened last Spring in Toronto.

These cars—which incidentally are an instance of Canadian aluminium returning to Canada after dollar-earning work has been done on it in Britain—were designed and built by the Gloucester Railway Carriage and Wagon Co., Ltd., who also supplied all the 100 steel cars now in service. It was decided to build the four aluminium cars, with two more to follow, in order to obtain an assessment of the economies of aluminium construction for this type of vehicle. Since the aluminium cars are identical with the steel ones in general design, capacity and power, a direct comparison of performance and operating costs will be possible. In a railway system of this type where stops and starts are frequent and brisk acceleration is called for (the steel cars can accelerate at 2·3 m.p.h. per second and reach 55 m.p.h.), weight-saving is obviously of value. Adoption of aluminium has resulted in a saving of 5½-tons per car, thus reducing the weight of the superstructure, complete with all equipment, from 22¼ tons to 16¾ tons. To assess comparative power consumption, kWh meters are fitted in the aluminium cars and in four steel cars. Another respect in which the aluminium cars are expected to show an economic saving is that of maintenance, since no external paint will be used.

The standard design of the Toronto cars, to which the light-alloy version conforms, has already been described at length in the technical press. In brief, the operating unit consists of two cars, one carrying the air-compressor and the other the auxiliary motor-generator set; a train may comprise up to four two-car units. The cars are large and spacious: 57 ft. long and over 10 ft. wide, with seating for 62 passengers and a total capacity of 230. Four 68 h.p. frame-mounted traction motors power each car: automatic retardation control is provided, and in general the equipment embodies many refinements, including elaborate heating equipment for pressure ventilation; special attention has been given to safety and to the suppression of noise and vibration.

In the case of the aluminium cars, the economics were investigated by the Aluminium Development Association, and recommendations were later made by the Association and by Northern Aluminium Co., Ltd., who supplied the structural material. Aluminium alloys, in the form of fully-heat-treated sections, plate, and sheet, were used for all structural members above the bogies, except the main bolster, which remains in steel.

Extensive use was made of the argon-shielded tungsten arc welding process, while in riveted joints, aluminium-alloy rivets to B.S.1473: NR5 were employed. The attachment of the external panelling is of special interest: the edges of the panels are butt-welded and attachment to the framing is by riveting, but in view of the high initial finish necessitated by the fact that no filling or painting was to be done, the riveting called for more than usual precision.

External and internal views of the aluminium subway cars, showing the absence of external painting and the clean and spacious interior.

Aluminium Billet Heating Furnace

Six-Lane Unit for Cable Sheathing

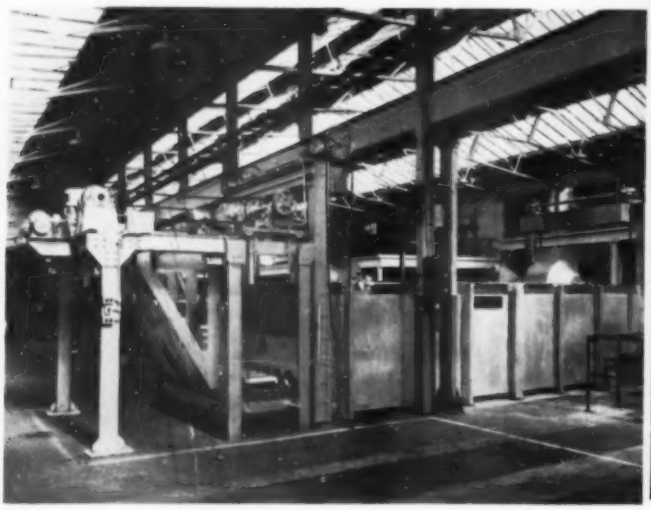
BRITISH INSULATED CALLENDER'S CABLES, LTD., have recently installed in their Prescot works new plant for the production of aluminium sheathed cable, the general features of which were described in our July, 1954, issue. The specially designed hydraulic press was ordered from the Loewy Engineering Co., Ltd., who also contracted to supply a suitable billet heating furnace to feed this press. The furnace selected was an electrically heated unit designed and installed by G.W.B. Furnaces, Ltd., of Dudley. The purpose of this article is to describe the furnace, which has several unusual features.

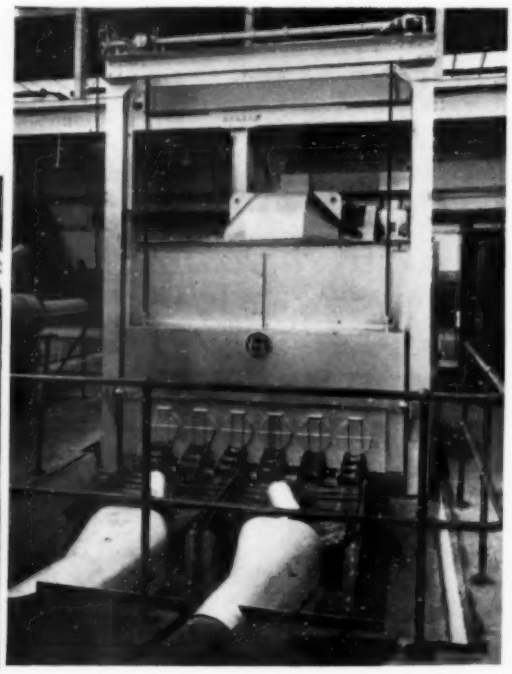
Reduced to simplest terms, the sheathing of the cable in the Loewy press involves the use of two billets, these being charged at the two ends of the horizontal container; the billets are extruded into tube through the core and die tools positioned mid-way along the length of the container and at right angles to the latter. The temperature of the billets supplied to the press is critical, as there must be equal deformation of them and also complete welding in the course of extrusion, in order to obtain a satisfactory product. The billet temperature required for sheathing direct on to some types of cable core is of the order of 300° C. or less, but the equipment may also be operated at temperatures up to 450° C. for other production purposes. The working range required on the furnace thus extends from less than 300° C. to a maximum of 450° C.

The furnace has an internal chamber 20 ft. long by 1 ft. 3 in. high, and six rows of diabolo-shaped idler rollers are fitted in the hearth. The size of the aluminium billets in the charge varies from 6¼ in. diameter × 12 in. long up to 9 in. diameter. × 18 in. long, and the maximum output for which the unit has been designed is 1,680 lb./hr. at 450° C. The total rating of 165 kW. is divided into two automatically controlled 10-ft. long zones, and spread evenly over the 3-phase mains supply. The first zone, where the initial heating of the billets takes place is rated at 105 kW.

As is normal practice in the temperature ranges involved, forced air circulation is provided, in this case from two double-entry scroll type fans, one of which is situated at each end of the furnace. The air is driven through the heating elements, situated in the upper portion of the furnace interior, towards the centre of the chamber, where it reverses direction and flows towards each end of the heating chamber. The nickel-chromium strip elements are suspended from removable plugs situated in the roof of the furnace, and are separated from the working chamber by insulated ducting. This ducting gives direction to the air flow, and also prevents direct radiation on to the charge. For ease of maintenance, the insulated covers over the fan housings are removable so that inspection of the impellers and bearings can be carried out without any difficulty. All the furnace interior is lined with aluminium-sprayed sheet steel, while the idler rollers are of cast iron.

Since the Loewy press requires two billets for sheathing the cable, the automatic discharge mechanism of the furnace is arranged to provide two billets at a time, heated to the correct extrusion temperature. The short end sections of the idler roller rows are arranged to incline so that the billets roll out under gravity. An





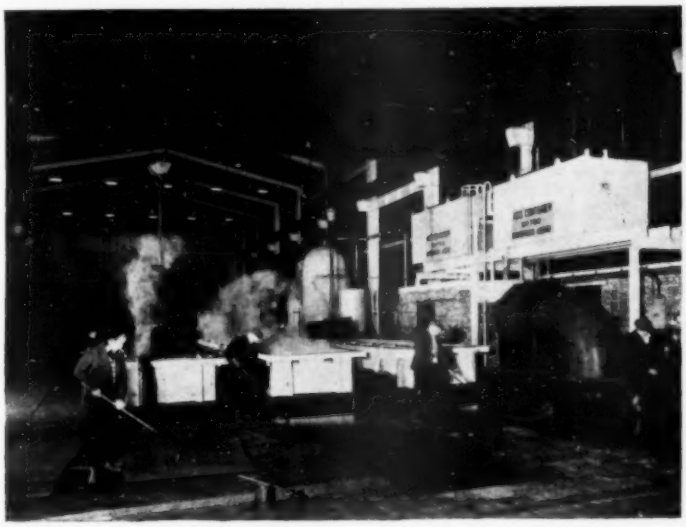
G.W.B. aluminium billet heating furnace. Left—charging end; right—discharging end.

electrically operated combined pusher gear and hoist is situated at the charging end of the furnace, while adjustable stops permit varying lengths of billet to be catered for.

Temperature control is effected by means of two Foster automatic indicating controllers, one for each zone, while a 2-point recording instrument gives a positive check on thermal conditions along the length of the heating chamber. This recorder is fitted with excess temperature safety contacts to protect the unit and the charge against accidental over-heating.

Whessoe's New Pickling Shop

Completion of £1,000,000 Works Reconstruction



WHESSOE, LTD., Darlington, have recently put the first part of their new pickling and painting shop into operation.

Pickling—the sulphuric/phosphoric acid (Footner) process for combating the corrosion of mild steel—has proved itself fully in the last 20 years. The demand for the initial protection of mild steel plates and sections used in plant for the oil, gas, chemical and other heavy industries has been steadily growing so that the shop built in 1936 has become too small. The new shop completes the works reconstruction programme on which Whessoe have expended £1,000,000 since 1946.

Since starting pickling in 1934 Whessoe have treated approximately half a million tons of steel plate and sections. At first one oil company was the sole user of pickled steel plates for oil storage tanks—one of Whessoe's chief products—but, as the process became known and its advantages as an anti-corrosive measure appreciated, its application has extended. Nowadays 80% of the total output of Whessoe is treated. Large tonnages of plate go to the oil industry, the gas industry increasingly favours its use for gasholders and purification plant, the chemical industry employs it for tanks and process vessels and it is also used for wind tunnels and similar structures.

History of the Process

Whessoe pioneered the pickling of heavy mild steel plates and sections in Great Britain in 1934, a year after Pfeiffer described the process to the first World Petroleum Congress. The phosphoric acid process used then consisted of descaling in a hot 10–15% solution of phosphoric acid, followed by immersion in a 2% solution at 85° C. to form a thin film of corrosion-inhibiting iron phosphate on the surface of the steel. Though giving satisfactory results, the process was expensive and in an effort to reduce costs the regeneration of the spent solution with sulphuric acid was tried for a time.

Finally, in 1936, Whessoe began to use the sulphuric acid/phosphoric acid process, which proved as effective as both previous processes and cheaper. It was the result of joint investigations by Shell Petroleum Co. and Whessoe. In this process millscale is removed in hot 5% sulphuric acid; the plate is then washed in hot water and finally immersed in 2% phosphoric acid at 85° C. The removal of millscale obviates the danger of accelerated corrosion and ensures that maximum life is obtained from the paint subsequently applied. The phosphoric acid bath gives a film of iron phosphate, which inhibits underpaint corrosion and provides an excellent key for paint.

Before the steel has time to cool appreciably, it is coated with good quality priming paint, which is brushed well into the hot phosphate filmed surface. The resultant priming coat will withstand rough handling during subsequent transportation and erection work and provides an excellent start for the final paint treatment.

Details of the New Shop

The new shop is 400 ft. long by 62 ft. wide by 37 ft. high to the eaves. It is of all-welded rigid frame construction with brickwork cladding and wire cast glass glazing, the roof being of Asbestos Trafford tiles and the floor generally of concrete. The shop is served by four overhead travelling cranes each of 7½ tons capacity.

The pickling baths, which are contained in an acid-resisting brick-lined pit, are of mild steel construction with an acid-resisting rubber lining protected from mechanical damage by a timber lining. These baths are of similar construction to those formerly used, but larger. The approximate dimensions are 33 ft. long by 5 ft. 9 in. wide by about 9 ft. 6 in. deep to take the larger plate sizes coming into use. Heating is by steam generated in a vertical tube oil-fired boiler fitted with automatic control. Both acid baths employ the "push-pull" type of fume extraction plant.

Correspondence

Grain Growth in Extrusions : Specifications : Oil Pipes

EXAGGERATED GRAIN GROWTH IN EXTRUSIONS

The Editor, METALLURGIA

Sir,

I should like to make an addendum to my article on "Exaggerated Grain Growth in Extrusions," which appeared in the December, 1954 issue of METALLURGIA, in that the review was originally undertaken as the initial part of a programme of research carried out in the Department of Industrial Metallurgy in the University of Birmingham. The results of this work will, it is hoped, be published shortly.

Yours faithfully,
D. H. Locke,
U.K.A.E.A.

Springfields,
February 8th, 1955.

SPECIFICATIONS AND TESTING

The Editor, METALLURGIA,

Sir,

It is indeed refreshing to learn, from your reference (under the title "Specifications and Testing" in your February issue) to Mr. J. M. Mowat's recent contribution to that subject[1], that the plea for co-operation between designer and manufacturer is gaining ground. In an article from my own pen, which was published in METALLURGIA some few years ago[2], I put forward this same plea, and Dr. Edwin Gregory had something on very similar lines to say in a paper before the Institution of Engineering Inspection[3].

Now I learn that Battelle scientists are taking action on these same lines: namely to form committees for "co-operation between all parties concerned, and especially between purchaser and manufacturer[4]", in the choice of materials.

The purpose of this letter is to endorse your own remarks, Sir, and to reiterate and to stress a view-point on a matter which is of so-far-reaching importance. To those who are not awake in this respect, I would say "wake up". To those who are already converted, I would say "continue the good work by converting your inspectors: especially those who hail from A.I.D., C.I.N.O., and C.I.A.".

Yours faithfully,
THOMAS B. CROW

Birmingham.
March 5th, 1955,

ALUMINIUM IN THE OIL INDUSTRY

The Editor, METALLURGIA.

Sir,

Mr. Bigford's interesting article on "Aluminium in the Oil Industry," in your February issue, makes a somewhat curious statement to the effect that "With the same diameter and wall thickness as for steel piping, the light alloy product will withstand the test pressures specified in specification A.P.I.5L with the same factor of safety." His results clearly show that the same test pressures can be withstood, but the factor of safety is surely quite different. For example, taking the best of his results on the $3\frac{1}{2}$ in. O.D. $\times \frac{1}{4}$ in. thick aluminium tube, the bursting pressure was 5,600 lb./sq. in. which is 2·24 times the test pressure of 2,500 lb./sq. in. A similar steel tube in A.P.I. Grade "B" material would withstand some 9,000 lb./sq. in. before bursting, which is 3·6 times the required test pressure. Similarly, for the $10\frac{3}{4}$ in. $\times$ 0·365 in. tube, the aluminium bursting pressure of 2,500 lb./sq.in. is 1·78 times the test pressure, while the corresponding value for steel of 4,000 lb./sq.in. would be 2·68 times the test pressure. Thus, the factor of safety for the steel is some 60% better than for the aluminium, and if the same factors of safety were to be obtained, the aluminium tubes would require to be about 55% thicker, namely 0·387 in. and 0·575 in., respectively, thus increasing the weight by a similar percentage. Even under these conditions, the much lower ductility of the aluminium compared with the steel would make it less suitable for many applications.

It is interesting to note that the best bursting pressures obtained with the two different sizes of aluminium tube correspond to stresses of 16·2 tons/sq.in. and 15·9 tons/sq.in., respectively. These are only about 85% of the nominal tensile strength of 19 tons/sq.in., and are practically the same as the yield point of the material.

It seems to us that an aluminium tube which bursts at a stress so near its yield point is hardly comparable with a steel one which, having the same yield point, would still sustain over 60% more pressure before bursting.

Yours faithfully,
J. S. BLAIR,
Stewarts & Lloyds, Ltd.

Corby,
February 14th, 1955.

The Editor, METALLURGIA.

Sir,

The comparisons made by Dr. Blair in his comments regarding the factor of safety would be more correctly described as the ratio of the test pressure to the bursting strength of aluminium and steel pipes. In the original article, the statement "with the same diameter and wall thickness as for steel piping, the light alloy product will withstand the test pressures specified in Specification A.P.I. 5L with the same factor of safety" simply means that the ratio between the working stress and the hydraulic test pressure is similar for both steel, and aluminium pipes of the same thickness. Hydraulic tests are required to be carried out in excess of the maximum working stress, and are not intended as a basis for design. This fact is indicated in the Note appended to paragraph 33, Section 5, p. 9, of Specification A.P.I. 5L.

Pipes for carrying fluids such as are described in Specification A.P.I. 5L are required to be designed on the yield stress of the steel specified. Such piping must not suffer a permanent change of the dimensions during

1 Mowat, J. M. "Acceptance Tests: What is Really Wanted". Paper before West of Scotland Iron and Steel Institute.
2 Crow, T. B. "That Specification: Master or Servant". METALLURGIA, 1950, **42**, 14-17; 59-63.
3 Gregory, E. "Formulation and Interpretation of Steel Castings Specifications". *J. Inst. Eng. Inspection*: Special Convention No., Sept. 1951.
4 Crow, T. B. "That Specification: Master or Servant". METALLURGIA, 1950, **42**, 62.

service; therefore, the plastic range of the material and its bursting pressure need not be considered. The material HT. 10-WP has a 0·2% proof stress which is equal to the yield stress of the specified Grade B. steel; therefore, it follows that pipes in aluminium and steel of the same dimensions will have the same resistance to permanent changes of dimensions.

Since there is no necessity to increase the thickness of the aluminium alloy pipe to give the same resistance to permanent deformation as steel, then the aluminium alloy pipe will have only one-third the weight of the equivalent steel pipe. Interesting confirmation of this fact is given in an article in the American journal *The Welding Engineer*, July 1950, entitled "Aluminium Pipe Lines", by W. B. Moore, that "for overhead river and stream crossings, and for bridge crossings, aluminium requires only one-third the weight of steel pipe of the same capacity."

When evaluating a material it is wrong to consider only one physical value, such as ductility, on its own, as all physical characteristics of the material should be weighed in the balance. It has been shown, however, that the ductility specified is adequate for this application. It is purely fortuitous that the stresses Dr. Blair has computed on bursting pressure values extracted from the paper correspond closely to the 0·2% proof stress. This is due mainly to the size of the specimens tested, and partly, in the case of the 3½ in. pipe, to the fact that the burst was not due to a hoop stress failure.

The advantages which aluminum alloys can offer, such as strength, light weight, high corrosion resistance to petroleum products, etc., are worthy of further consideration by petroleum engineers.

Yours faithfully,

H. M. BIGFORD,

Development Metallurgist, T.I. Aluminium, Ltd.
Birmingham, March 18th, 1955.

New and Revised British Standards

WROUGHT STEELS IN THE FORM OF BARS, BILLETS AND FORGINGS
(B.S.970 : 1955) PRICE 12s. 6d.

B.S.970 : 1955 specifies requirements for wrought steels in the form of bars, billets and forgings up to 6 in. ruling section. It also sets out the chemical compositions of En steels which are normally supplied in the form of plate, sheet, strip and wire; for such products, however, reference should be made to :—

B.S.1408 : "Hard Drawn Steel Wire for Springs."
B.S.1429 : "Annealed Steel Wire for Oil Hardened and Tempered Springs."
B.S.1449 : "Steel Plate, Sheet and Strip."
B.S.1554 : "Rust, Acid and Heat Resisting Steel Wire."
B.S.2056 : "Rust, Acid and Heat Resisting Steel Wire for Springs."

To ensure the alignment of this series of standards, B.S.1449 will shortly be issued in revised form, and B.S.1408 and B.S.1429 have been amended.

The first edition of B.S.970 appeared in 1947. Its successor incorporates the results of research and experience during eight vital and progressive years in the iron and steel industry's history. Also included are the case hardening steels of the En 350 and En 360 series, which were issued as Emergency Specifications in 1951, but which have since become established as standard steels. Other features which will enhance the usefulness of the standard are: the coverage of Service requirements, so far as they are compatible with those of industry as a whole, an improved layout, and a revised arrangement of the contents.

The B.S.I.'s forthcoming issue of a German translation of B.S.970 effectively underlines the importance which industry and the Institution attach to the document. This innovation will make the standard available in readily understood form to German-speaking engineers throughout the world.

METHOD FOR THE DETERMINATION OF IRON IN ORES, SLAGS AND REFRACTORIES
(B.S.1121 : PART 33 : 1955) PRICE 2s. 6d.

THIS new Part of B.S.1121 is in two sections, the first being a volumetric method with a range of 0·05–100% iron. In this method the solution of the sample in sulphuric or perchloric acid is reduced by hydrogen sulphide and any precipitated sulphides are filtered off. Excess hydrogen sulphide is eliminated by boiling, and the ferrous iron is titrated with a standard potassium dichromate solution, using barium or sodium diphenylamine sulphonate as an internal indicator. The second section deals with an absorptiometric method which has a range of 0·01–1% iron. A sulphuric acid solution of the sample is prepared and the iron converted to a coloured complex with thioglycollic acid.

METHODS FOR THE ANALYSIS OF ALUMINIUM AND ALUMINIUM ALLOYS
PART 6 : IRON (VOLUMETRIC TITANOUS CHLORIDE METHOD)
PART 7 : ZINC (ZINC OXIDE METHOD)
(B.S.1728 : 1955) PRICE 2s. EACH PART

PART 6 of B.S.1728 : 1955 relates to the volumetric determination of iron for use with alloys containing between 0·1% and 5% iron; and Part 7 deals with the determination of zinc by the zinc oxide method. This is an additional method to those specified in Parts 3 and 4 (already issued). The method is for use with alloys having a zinc content of 2–15%. The methods specify the reagents to be used, recommended methods of sampling and test procedure. An indication of the reproducibility expected is given, and is derived from experiments carried out by a number of independent analysts.

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1.

Change of Address

BRITISH INSULATED CALLENDER'S CABLES LTD. announce that the new address of their London Branch Sales Office is 10/14 White Lion Street, London, N.1. The telephone numbers are TERminus 8696 and 0372. It should be noted that the Company's Central Administrative Offices remain at 21, Bloomsbury Street, London, W.C 1.

NEWS AND ANNOUNCEMENTS

Iron and Steel Institute A.G.M.

THE Eighty-Sixth Annual General Meeting of The Iron and Steel Institute will be held on Wednesday and Thursday, 27th and 28th April, 1955, at the offices of the Institute, 4 Grosvenor Gardens, London, S.W.1.

Following the business meeting and the presentation of medals and prizes on the Wednesday morning, the new President, SIR CHARLES BRUCE-GARDNER, Bt., will deliver his Presidential Address. This will be followed by the presentation and discussion of a paper on "The Gas Turbo-Driven Blower for Blast-Furnace Service," by C. E. SAYER (*April*, 1955). The papers to be discussed in the afternoon will deal with the charging of open-hearth furnaces: "Charging Delays due to Furnace Bunching," by R. SOLT (*April*, 1955); and "The Supply of Scrap to Open-Hearth Furnaces," by M. D. J. BRISBY and W. O. PENDRAY (*April*, 1955).

Creep will be the subject for discussion at the Thursday morning session, when the following papers will be presented: "Causes of Variable Creep Strength in Carbon Steel," by W. E. BARDGETT and M. G. GEMMILL (*March*, 1955); "Creep and Rupture Data on Mo, Cr-Mo and Mo-V Steels," by J. GLEN (*April*, 1955); "Statistical Study of Creep and Fatigue Properties of a Precision-Cast High-Temperature Alloy," by G. T. HARRIS and H. C. CHILD (*November*, 1954); and "Relationships between Long and Short Time Creep and Tensile Properties of a Commercial Alloy," by A. GRAHAM and K. F. A. WALLES (*February*, 1955). In the afternoon, vanadium pentoxide attack on gas-turbine alloys will be discussed on the basis of the following papers: "Mechanism of Accelerated Attack on Metals and Alloys by V_2O_5," by G. LUCAS, H. WEDDLE and A. PREECE (*March*, 1955); and "Effect of Composition of Gas Turbine Alloys on Resistance to Scaling and to V_2O_5 Attack," by G. T. HARRIS, H. C. CHILD and J. A. KERR (*March*, 1955).

The dates following the names of the authors refer to the issue of the *Journal of the Iron and Steel Institute* in which the particular papers were published.

Foundry Atmosphere Control

B.C.I.R.A. Conference at Harrogate

A CONFERENCE on foundry ventilation and dust control, organised by the British Cast Iron Research Association, Alvechurch, Birmingham, will be held at the Hotel Majestic, Harrogate on 27th–29th April, 1955. The conference will lay particular emphasis on measures to be taken to meet the new statutory regulations referring to dust and fume with which all foundries must comply as from 1st January, 1956.

Much interest was aroused by the publication, since the War, of the Report of the Joint Advisory Committee on Conditions in Ironfoundries (now commonly known as the Garrett Report, after the name of Sir Wilfrid Garrett, the Chairman of the Committee). In 1951, the Association set up a Foundry Atmospheres Team to enquire into the control and elimination of dust and fume in various foundry operations, and into the possibilities of improving general foundry ventilation. The present conference thus provides an opportunity to survey the progress made so far, particularly with reference to the control of dust at the knockout station (at which point the casting is shaken out of the mould and most of the sand is removed), and in fettling and grinding operations. Other contributions will deal with general foundry ventilation and with the suppression of dust in specific operations.

All the members of the B.C.I.R.A. Foundry Atmospheres Team will be taking part in the conference, and a number of other lecturers experienced in problems of dust control and foundry ventilation, or concerned with the design of equipment, will also present papers, among which will be contributions from France and the U.S.A.

While the conference is primarily intended for the iron-founding industry, firms engaged in related industries in which dust problems of a similar nature occur are expected to send representatives. The President of the Association, Mr. S. H. Russell, Chairman and Managing Director of S. Russell and Sons, Ltd., Leicester, will welcome visitors at the opening session on 27th April. Sir George Barnett, H.M. Chief Inspector of Factories, will introduce the conference with a contribution on health and safety in the foundry industry.

Harrogate, the centre chosen, is able to provide accommodation for large numbers of visitors, since it is not the Association's intention to repeat this conference.

Beilby Memorial Awards, 1954

THE Administrators of the Sir George Beilby Memorial Fund, representing the Institute of Metals, the Royal Institute of Chemistry and the Society of Chemical Industry, have made awards from the Fund for 1954, each of one hundred and fifty guineas, to:—

H. K. HARDY, M.Sc., Ph.D., A.R.S.M., in recognition of his work in physical metallurgy, with special reference to precipitation hardening and to the thermodynamics of phase equilibria in alloy systems.

J. W. MENTER, M.A., Ph.D., A. Inst.P., in recognition of his work on surface phenomena, with special reference to the application of electron optical techniques to the elucidation of a wide range of problems.

Awards from the Fund are made to British investigators in science as a mark of appreciation of distinguished work, particularly in such fields as fuel economy, chemical engineering and metallurgy, in which Sir George Beilby's special interests lay. In general, the awards are not applicable to more senior investigators, but are granted as an encouragement to relatively young men who have done independent work of exceptional merit over a period of years.

Metallurgy of Joining Lectures

A SERIES of eleven lectures, by authorities in their particular fields, on "The Metallurgy of the Joining of Metals," will be given weekly in the Department of Metallurgy at Battersea Polytechnic, commencing on the 27th April. The particulars of the successive lectures are: "The Metallurgical Principles Involved in Jointing," by J. P. MOORE (Battersea Polytechnic); "Soft Soldering, Brazing and Silver Soldering," by DR. J. C. CHASTON (Johnson Matthey & Co., Ltd.); "Welding Techniques," by W. K. B. MARSHALL

(Rockweld, Ltd.); "The Metallurgy of the Welding of Carbon and Alloy Steels," by E. D. DOLAN (British Petroleum Co., Ltd.); "The Metallurgy of the Welding of Cast Irons," by J. HINDE (Mond Nickel Co., Ltd.); "The Metallurgy of the Welding of Stainless and Heat Resisting Steels," by J. A. MCWILLIAM (Firth-Vickers Stainless Steels, Ltd.); "The Metallurgy of the Welding of Copper-Base Alloys," by DR. R. A. CRESSWELL (British Oxygen Co., Ltd.); "The Metallurgy of the Welding of Light Alloys," by J. F. LANCASTER (A.P.V. Co., Ltd.); "Weldability," by J. F. MERCER (Murex Welding Processes, Ltd.); "The Testing of Metal Joints," by S. W. HOLLINGUM (Ministry of Supply); and "Plastic Bonding," by R. A. JOHNSON (Aero Research, Ltd.).

The inclusive fee for the course is £3. 3s. 0d. Further particulars can be obtained from the Secretary (Metal Joining Course), Battersea Polytechnic, London, S.W.11.

Iron and Steel Institute
Awards of Medals and Prizes

Bessemer Medal: The Bessemer Gold Medal for 1955 has been awarded to PROFESSOR JOHN CHIPMAN, Head of the Department of Metallurgy, Massachusetts Institute of Technology, in recognition of his distinguished contributions to the knowledge of the physical chemistry of steelmaking.

Sir Robert Hadfield Medal: The Sir Robert Hadfield Medal for 1955 has been awarded to MR. TOR FJALAR HOLMBERG, of Oy Vuoksenniska A.B., in appreciation of his meritorious service in improving the technique of the production of iron and steel at the Imatra Works, Finland.

Andrew Carnegie Silver Medal: An Andrew Carnegie Silver Medal for 1954 has been awarded to MR. B. CINA for his paper on the "Effect of Cold Work on the *Gamma-Alpha* Transformation in Some Iron-Nickel-Chromium Alloys." (*Journal* 1954, Vol. 177, August, 406–422).

Williams Prizes: Three Williams Prizes of £100 each have been awarded for 1954, as follows: £100 to MR. W. JACKSON for his paper on "The Use of Cold Coke Oven Gas and Pitch-Creosote Firing on Tilting Furnaces." (*Journal* 1954, Vol. 178, December, 378–390); £100 to MR. R. MCDONALD for his paper on "Steelworks Waste Heat Boiler Practice." (*Journal* 1954, Vol. 176, January, 71–92); and £100 to MR. A. STIRLING for his paper on the "Pelletizing of Northampton Sand Ironstones by Vacuum Extrusion." (*Journal* 1954, Vol. 177, May, 25–42).

Safety and Factory Efficiency Exhibition

ARRANGEMENTS for the Third Safety and Factory Efficiency Exhibition, organised by the Birmingham and District Industrial Safety Group, are progressing satisfactorily. The exhibition, which will be held at Bingley Hall, Birmingham, is to be officially opened on Friday, 24th June, and will continue for one week. New exhibitors number 22 and there will be at least 50% more space occupied by exhibitors' stands than at the last exhibition. A large section of the exhibition will be devoted to an "Ideal Factory Feature," and members of the Birmingham Productivity Association have plans in hand for showing "a factory of the future."

During the opening week-end, a residential congress will be held to discuss topics under the general title of "A Social and Factual Examination of Industrial Accidents." Opportunity is also being taken to arrange a series of day and half-day conferences during the week, and the Institute of Industrial Supervisors, Institution of Works Managers, Institute of Personnel Management and the British Electricity Authority have already agreed to take part.

City and Guilds Insignia Awards

THE Insignia Award in Technology was instituted by the City and Guilds of London Institute in November, 1952, with the intention that it should be a mark of distinction for those who have combined sound practical training with an adequate knowledge of the fundamental scientific principles of their subject, and who show a capacity for leadership and administration, and for applying their wider knowledge effectively in the industry. Since its inception the development of the scheme has been both steady and encouraging, and the standard of the award has been maintained at the high level envisaged by the Institute; it is interesting to note that of 43 theses so far received from candidates, 15 failed to satisfy the assessors, and of the remainder 9 failed to satisfy the interviewing panels.

At a recent meeting of the Council of the Institute, awards were conferred upon 9 candidates, bringing the total of awards by thesis and interview to 19. Among the recent recipients was MR. C. H. RUMBLE (Chemical Industries—Non-Ferrous Metallurgy) whose thesis was entitled "Modern Methods of Production of Matrices for the Manufacture of Transcription and High Quality Long-Playing Records."

In addition, special awards have been conferred by the Council in respect of the year 1955 to persons of distinction in their industry who, in their early days, gained City and Guilds' Certificates or equivalent qualifications. Those so honoured included DR. L. AITCHISON (Chemical Industries—Metallurgy) and DR. E. CARR (Constructional Industries—Metallurgy as Applied to Building Construction).

Empire Mining and Metallurgical Congress

THE Empire Council of Mining and Metallurgical Institutions have pleasure in announcing that the Sixth Empire Mining and Metallurgical Congress will be held in Canada during 1957, by kind invitation of the Canadian Institute of Mining and Metallurgy. Full particulars are expected to be circulated within the next few months to members of the principal mining and metallurgical societies in the Commonwealth. Meanwhile, some particulars will be available from the Honorary Secretary, Empire Council of Mining and Metallurgical Institutions, 438, Salisbury House, London, E.C.2, England.

Sir William Larke's Eightieth Birthday

SIR WILLIAM J. LARKE, K.B.E., who will be eighty on 26th April next, is to be the guest of honour at a Luncheon organised by the Institute of Welding and the British Welding Research Association at the Hyde Park Hotel on the previous day. The Chair will be taken by Sir Claude Gibb, F.R.S., supported by Sir Charles Lillicrap, K.C.B., M.B.E., Chairman of Council of the

British Welding Research Association, and Mr. R. G. Braithwaite, President of the Institute of Welding. Further particulars and tickets are obtainable from the Secretary, Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1.

Aluminium in Shipbuilding Symposium

A JOINT Symposium on the Use and Welding of Aluminium in Shipbuilding is to be held in London at the Institution of Naval Architects on December 7th and 8th, 1955. An Organising Committee has been established, representing the Institute of Welding, the Institution of Naval Architects, the British Shipbuilding Research Association, the British Welding Research Association, and the Aluminium Development Association. The Secretary of the Symposium is Mr. G. Parsloe, the Secretary of the Institute of Welding.

Personal News

MR. E. A. HYDE has been appointed Deputy Managing Director, and MR. W. V. HODGSON, Assistant Managing Director, of Wickman, Ltd. Mr. Hyde, who joined the Company in 1944, has been Financial Director since 1945. Mr. Hodgson, who joined the Company in 1947, has been General Manager of the Machine Tool Division since 1949, and was appointed to the Board in 1953.

MR. L. K. PARKER, telecommunications consultant to the Telephone Manufacturing Company, Ltd., since 1952, has joined Winston Electronics, Ltd., as Chief Sales Engineer.

MR. C. PULLAN, Sales Director of Armstrong Whitworth (Metal Industries) Ltd., and Jarrow Metal Industries, Ltd., is expected back in England in early April from a business tour of South Africa which included visits to Capetown, Johannesburg, Pretoria, Bulawayo and Salisbury. In discussing the general business of the two Companies, Mr. Pullan has been particularly concerned with the sales of Closeloy Rolls and Kue-Ken Crushers.

AIR MARSHAL SIR VICTOR GODDARD, K.C.B., C.B.E., has joined Elliott Brothers (London) Ltd., as an Assistant (Air) to the Managing Director.

BRITISH INSULATED CALLENDER'S CABLES, LTD., announce the appointment of MR. R. H. STEEDS as Regional Manager (Scotland). His headquarters will be the Company's Glasgow Office.

MR. W. V. BINSTEAD has joined the Development Department of the British Welding Research Association. The Association is expanding its development service and, during the next two years, will be holding a series of lectures on " Increased Productivity due to Welding " in many parts of the country. This programme, which Mr. Binstead is organising, has been made possible as a result of American funds made available by the Department of Scientific and Industrial Research.

MR. D. F. CAMPBELL, Chairman of Electric Furnace Co., Ltd., recently presented gold watches to nine members of the staff for service with the EFCO Group of Companies for twenty-five years or more.

SANDERSON BROTHERS & NEWBOULD, LTD., have appointed MR. K. J. PROCTOR of 11 Woodburn Road, Northenden, Manchester (Tel.: Wythenshawe 4648), as their representative in Lancashire, Cheshire, North Wales and Westmorland.

MR. A. G. THOMPSON, a member of B.W.R.A. staff, will be attending the intra-European Mission for the comparative study of welding techniques as a specialist in welding productivity nominated by the European Productivity Agency.

DR. R. W. K. HONEYCOMBE, Senior Lecturer in Physical Metallurgy in the University of Sheffield, has been appointed to the Chair of Physical Chemistry in succession to PROFESSOR QUARRELL who, last November, was appointed head of a single department combining the Post-Graduate School in Physical Metallurgy and the Department of Metallurgy. Dr. Honeycombe graduated in metallurgy at the University of Melbourne in 1942 and came to this country with an I.C.I. Fellowship to work in the Cavendish Laboratory at Cambridge as a member of Dr. Orowan's Metal Physics Group.

MR. A. O. BLUTH has joined the Board of Vickers, Ltd. He is a Director of Vickers Armstrongs, Ltd., a Director of Erlangers, Ltd., and Vice-Chairman and Joint Managing Director of the Jack Olding Organisation.

DR. A. H. COTTRELL, Professor of Physical Metallurgy in the University of Birmingham, who is well-known for his research work, both theoretical and practical, concerning the mechanical properties of metals, has been elected a Fellow of the Royal Society.

MR. E. S. WADDINGTON of Philips Electrical, Ltd., Industrial Division, has been elected Vice-Chairman of the Arc Welding Plant Section of B.E.A.M.A.

MR. R. H. GUMMER, a Director of International Combustion, Ltd., and associated companies, has been elected President of The Institute of Fuel, and will take office in October next.

Obituary

The Late F. G. Connor

BY the untimely death of Francis G. Connor, the Managing Director of the Metallurgical Equipment Export Co., Ltd., the country has lost an engineer of great ability and wide experience. Mr. Connor died suddenly, on February 28th, of a heart attack while visiting Caracas in Venezuela, at the age of 55.

He joined the Electric Furnace Co., Ltd., in 1928. In 1945 he was appointed Managing Director of the newly-formed Metallurgical Equipment Export Co., Ltd., an organisation co-ordinating certain export activities of a number of the leading British makers of heavy metallurgical equipment. He was also a Director of Campbell, Gifford & Morton, Ltd., Consulting Engineers. He travelled far and wide, and was well known in metallurgical circles in the U.S.A. and in many South American and European countries. Recently he was actively engaged in negotiating successfully large contracts for the export of metallurgical equipment for Government steelworks in Norway and Spain.

Mr. Connor was a strong supporter of educational and religious organisations in the Walton and Weybridge district of Surrey, where he lived. His death will be a great loss to his many friends and associates, who widely recognised his great ability in presenting the essence of complicated international transactions in straightforward language that could be easily assimilated by technical, financial and Government officials. His linguistic attainments and remarkable memory were also of immense value in negotiations with foreign customers.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Brightray H.

HENRY WIGGIN & CO., LTD., have introduced a new grade of nickel-chromium alloy for high-temperature furnace resistors. This is a modified 80/20 nickel-chromium alloy intended for use as a heating element in electric resistance furnaces where the element operating temperature exceeds that for which Brightray S is normally suitable. The new grade is intended for elements operating in the temperature range 1,100/1,250° C.

Brightray H has been developed as a result of extensive work carried out in the Research Laboratories of The Mond Nickel Co., Ltd., and is now in production in the form of rod, wire and strip. It has been under test in the laboratory for several years and has proved successful in several metallurgical heat-treatment furnaces and for high-temperature firing of pottery.

Oxidation resistance of the new alloy at temperatures above 1,100° C. is better than that of the standard 80/20 nickel-chromium alloy. Laboratory tests on strip 0·88 mm. thick × 14 mm. wide and on rod heated continuously in air to 1,250° C. gave lives of over 1,000 hours. This shows a considerable improvement over the life which can be obtained with the standard 80/20 nickel-chromium alloy in similar conditions.

The specific resistance of Brightray H at room temperature is 126–130 microhms/sq.cm./cm. This increases by 3·6–4% as the temperature is raised to about 450° C., and decreases by 6–9% between 450 and 900–1,000° C. As the temperature is further increased, the specific resistance rises slightly, but up to 1,300° C. remains less than the value at room temperature. The density at 20° C. is 7·8–8·1. Brightray H has excellent high-temperature strength and does not embrittle in service.

Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham, 16.

Hot Spraying Anti-Corrosive Compounds

THE Regent Oil Co., Ltd., and the Atlas Diesel Co., Ltd., have recently co-operated in developing a hot spray method for applying semi-solid anti-corrosive compounds. The difficulties of effectively spraying such compounds are well-known, and more often than not excessive quantities of thinners are required. Consequent evaporation after application may result in an inadequate coating as well as contaminating the atmosphere with solvent vapours. The other and normal alternative is to apply the compound with a brush. This method is time-consuming and often quantitatively wasteful, as well as giving an uneven finish and insufficient coverage in spots not easily accessible with a brush.

The newly developed " hot spray process " is the result of experiments with the Regent Oil Co.'s Caltex Rustproof Compound L and the Atlas Diesel Co.'s KV3 Cup Heater and Ecco 306 Spray Gun. The compound, which contains 12% volatile thinner, is heated in the cup heater to 140° F.–160° F. (melting point 120° F.–125° F.). When the thinner has evaporated after application the melting point is 145° F. The compound is sprayed at a pressure of 45 lb./sq.in. by the special internal-mix Ecco 306 gun, which gives the required atomisation. When the globules strike the surface being sprayed, they congeal immediately, thus eliminating wasteful backspray and producing an even coating that covers effectively.

Compound L, a semi-solid, is a blend of mineral oils and petroleum jelly containing special additives, which give it non-drying, flexible and high by adhesive qualities, thus providing a protective coating or film that does not harden or crack, that will withstand rough treatment and tropical or arctic temperatures. None of these qualities are lost by use of the hot spray method. An advantage of Compound L is that it can be sprayed on a surface that is not completely free of moisture. The film or coating absorbs any moisture and then expels it to the " weather " side where it is lost through evaporation.

Regent Oil Co., Ltd., 117 *Park St., London, W.1.*
Atlas Diesel Co., Ltd., Beresford Avenue, Wembley, Middlesex.

New Range of Ventilated Motors

THE English Electric Company is now manufacturing a new range of small, highly efficient, ventilated squirrel-cage induction motors having outputs from ½ to 25 h.p. These motors, known as the Class LE, have dimensions that comply with the revised standard of the United States National Electrical Manufacturers' Association (N.E.M.A.), which calls for smaller motors in four frame diameters. They will thus be particularly suitable for manufacturers exporting machine tools to dollar areas, and also for the users of American machine tools, who will now be able to obtain the correct motor in this country.

Following the successful introduction of the " English Electric " Class LY, totally-enclosed fan-cooled British Standard Dimensioned motor, it was evident that there was still a wide demand for a ventilated machine. As N.E.M.A. was introducing a new standard for ventilated

motors, calling for dimensions smaller than British Standard, it was decided that the new motors should comply with N.E.M.A. requirements, as it was considered that to make machines larger than necessary would be a retrograde step. Motors of the new range are available for operation at any standard supply frequency and voltage, and the bearings are of metric sizes so that they are obtainable anywhere in the world.

The end-shields of the motors have wide flares to allow maximum air flow, and the vents are fully protected. A novel feature is the "trap-type" cavity in which the axial fan rotates. This arrangement provides a voluminous air-stream and ensures a cool-running machine under the most arduous conditions.

All machines comply with British Standard 168 : 1936, have the approval of the Canadian Standards Association, and meet the requirements of the Factories Act

The English Electric Co., Ltd., Queens House, Kingsway, London W.C.2.

A Remote Printing Counter

An interesting new instrument has recently been developed by Foxboro-Yoxall, Ltd., for use at the new Kwinana Refinery now being built in Western Australia by the Anglo-Iranian Oil Co., Ltd. A large number of instruments were required to take flow measurements from different parts of a process and deliver the information at a remote central point. Normally such a problem would be met by employing a flow meter and a Foxboro Type 24 Electric Integrator which would give a visual reading. However, in this case it was further required that the system should provide permanent easily taken readings in a form convenient for clerical handling. To meet these needs Foxboro-Yoxall have designed the new Remote Printing Counter which takes the impulses of the electric integrator and automatically prints the total flow readings on a card inserted by the operator.

The remote printing counter has been designed with particular care as to its printing system, because up to 50 of the instruments will be in simultaneous service, and the possibility of error in the taking of readings had to be reduced to a minimum. To this end a colour system is used, whereby each instrument or group of instruments prints in a particular colour, and has an indicating disc of this colour on its surface. The card is also overprinted in this colour, so that when the operator inserts, for example, a red card into a red instrument he gets a red printing. If not, he knows he is in error. The reading from each instrument shows the time and the flow figure, and is printed at a designated position opposite the appropriate meter number and factor, the latter being overprinted on the card as a further precaution against error. Thirteen such readings may be recorded on one card.

The mechanism of the remote printing counter consists primarily of a train of wheels which have on their rims the relevant type, and are driven and controlled by electric motors energised by the electric integrator. A reading is taken by inserting a card in the slot on the face of the instrument : no other action is needed, the entry of the card itself causing the mechanism to print the time and the flow reading in the correct space.

Foxboro-Yoxall, Ltd., Lombard Road, Merton, London, S.W.1.

Epoxy Resins for Plastic Patterns

The versatile epoxy resins are now being produced for making plastic patterns, and, it appears, offer marked advantages over other resins that have been tested for this purpose. Aero Research, Ltd., who are responsible for the development of Araldite Casting Resin M for pattern making, state that shrinkage on setting is very low indeed, and quite negligible when fillers are used. It is also claimed that the hardened resin is tough, durable and dimensionally stable. Araldite Casting Resin M sets cold in 24 hours, or in a shorter time if gentle heat is applied. As shrinkage and brittleness have hitherto been regarded as inherent defects of plastic patterns, the introduction of the epoxies into this field will arouse considerable interest in foundries, and should contribute significantly towards reducing high costs.

Aero Research, Ltd., Duxford, Cambridge.

New Mould Resistant Paint

Allweather Paints, Ltd., have recently developed a chlorinated rubber based mould resistant paint. This has been achieved by incorporating a fungicide which will not cause embrittlement or other deterioration of the paint film. The main constituent is mercury, which is well-known for its fungicidal properties in protective

paints. This mercurial addition is permanent and insoluble in water and will not, therefore, evaporate or leak, or crystallize out of the film on exposure, and will remain effective for the service life of the paint.

Apart from the fungicidal properties of the mercury, the use of chlorinated rubber as the paint's base is advantageous in that, unlike linseed and vegetable oils, chlorinated rubber has no nutritive value for those fungi which fatten on oils. Chlorinated rubber paints provide a relatively impermeable paint film, which is another advantage, since it has been shown that the presence of moisture in a paint film attracts mould formation. However, the paint film must not be too impermeable otherwise the toxic mercury compound cannot act. The fungicide in the final film is non-toxic, except, of course, to fungi.

Allweather Paints, Ltd., 36, *Gt. Queen Street, London, W.C.2.*

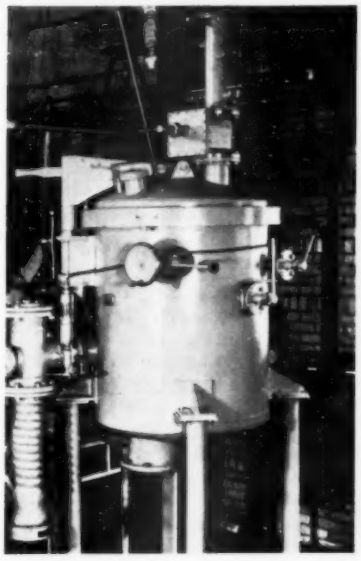
Protective Aprons

HIGHER resistance to abrasion, chemicals, and water, longer service life, and increased comfort in use, due to reduction in the weight of material, are a few of the advantages claimed for North P.V.C. protective aprons

which are made from an extremely hard-wearing fabric, impregnated and proofed with a North formulation of P.V.C. The finished product is light, flexible, non-ageing, non-oxidising and non-deteriorating, and its tack-free surface minimises the retention of dirt and grime. For work involving excessive abrasion, additional protection can be provide by a reinforcement patch on the front of the apron. Standard weight black or brown aprons are used for heavier work, whilst extra-light aprons in khaki or white are suitable for duties calling for lightweight protection.

James North & Sons, Ltd., Godley Mills, Hyde, Cheshire.

New 30-lb. Vacuum Furnace



A NEW 30-lb. induction-heated vacuum furnace is now offered by Naresco Equipment Corporation, equipment sales subsidiary of National Research Corporation. Available with either a vertical or horizontal shell, it is a completely self-contained, versatile furnace for research and development purposes. Among its unique features are a co-oxial power feed-through, and means for adding additional charge material or alloying material during melting, without losing the vacuum. The illustration shows this furnace, with a vertical shell, installed in National Research Corporation's metallurgical laboratory.

Naresco Equipment Corporation, 160 *Charlemont Street, Newton Highlands*, 61, *Mass., U.S.A.*

Fast X-ray Film

INDUSTRIAL radiographers will be interested in the new increased speed Kodirex X-ray film. This new film, which is the fastest of its type, yields images of high contrast and with resolution of detail fully adequate for work in which a high-speed material is required. It is recommended for all techniques demanding a very fast film, either in direct-exposure work or for exposures with lead intensifying screens.

When the exposure must be short and the more critical inspection offered by Kodak Industrex Type D and Crystallex X-ray films is not warranted, the new film offers marked advantages in saving exposure time, increasing the output of X-ray departments, and extending the life of the X-ray tube.

In gamma-radiography, the new film is particularly useful, for it enables many hours to be saved on exposures without serious loss in the diagnostic value of the radiograph. Short exposure times also make the film of interest to X-ray crystallographers. The straight-line relationship between density and exposure is good and resolution is adequate for fine-line separations.

Kodak, Ltd., Wealdstone, Harrow, Middlesex.

CURRENT LITERATURE

Book Notices

HOT DIP GALVANISING

Edited Proceedings of the Third International Galvanising Conference held at Oxford, 1954. 280 pp., 137 illustrations (19 in colour). 1954, Zinc Development Association, Lincoln House, Turl Street, Oxford. 42s.

THIS official publication contains the full texts of the papers presented at the conference and of the discussion which took place, incorporating the authors' revisions, together with written contributions received subsequently. A special feature of the book is that, in its editing, particular care has been taken to maintain a logical presentation of the material, and consequently papers have been linked together in the chapters, where appropriate, and a considerable rearrangement of the discussions has been made. The 17 papers by authors from six European and American countries provide 12 chapters in the Proceedings.

The first Chapter "Galvanising Survey" contains a paper by MR. R. LEWIS STUBBS, Director of the Zinc Development Association, surveying recent progress in galvanising, and giving statistical information on the industry in Britain, Europe and the free world. After describing the general structure of the British industry, the paper considers recent improvements in plant design and heating methods, the growth of continuous strip galvanising, and new techniques for protecting structural steel. In discussion, the relative fields of application for hot dip galvanising and the recently developed hot dip aluminising are defined, and the organisation of the newly formed Dutch Galvanising Institute is explained.

Chapter II, on "Sheet and Strip Galvanising," commences with a paper on "The Development of Continuous Galvanising in the United States" by MR. N. E. COOK of Wheeling Steel Corporation. This outlines the historical development of continuous galvanising, and describes in detail the new Cook-Norteman process in which electric induction heating is used and a close positive control of coating adhesion is possible. In discussion, many comparisons are drawn with the established Sendzimir process, also considered in the second paper by MR. J. LANDEAU, of Fours et Gazogenes Heurtey, which discusses the optimum thermal factors necessary for maximum output in galvanising cold sheets and continuous strip. Faults in galvanised sheet are discussed in Chapter III in a paper by DR. H. WIESTER and DR. D. HORSTMANN of the Max-Planck Institut für Eisenforschung; this is a brief illustrated review of research concerned with faults arising in the basic steel, at the pickling or annealing stages, and in the galvanising bath. In the discussion, work on similar lines by the British Iron and Steel Research Association is described.

Chapter IV on "Galvanised Tubes" contains two papers. In the first, DR. R. HAARMANN, now of Siegener A.G., gives a comprehensive review of methods of pretreating tubes before galvanising, including details of special ovens for drying and pre-heating. In the second, MR. A. CLIFT, of Stewarts and Lloyds, Ltd., describes the uses of galvanised tubes at the present time, with particular emphasis on urban and agricultural service piping and structural uses. In the first paper of Chapter V on "Wire Galvanising," MR. R. SOUSKE, of Zinc et Alliages, describes a comprehensive series of accelerated tests designed to study the composition of wire galvanising baths, and concludes that additions of aluminium and cadmium to electrolytic zinc will increase the adherence and corrosion resistance of the galvanised coating. In the second paper, MR. L. CAZZANIGA, of Pietro Cazzaniga s.r.l., describes an Italian wire galvanising process, in which the wire is heated electrically, and degreasing and pickling are combined in one operation; the process is claimed to give high outputs and substantial operating economies.

Chapter VI on "Galvanising Threaded Parts" consists of a paper by MR. A. GORDET, of Zinc et Alliages, which describes research work undertaken to enable bolts and nuts to meet the specifications of the French public services (a minimum of 1·64 oz./sq. ft.), and the pre-treatment, galvanising and centrifuging techniques which were evolved.

Chapter VII on "The Costing of General Work" contains much information, useful mainly to general galvanisers, not usually found in technical books of this nature. Two papers which describe the basic principles of cost estimating are included, by MR. J. H. MAYBERRY of the Oliver Iron and Steel Corporation, U.S.A., and MR. L. F. CHAMBERS of G.A. Harvey & Co. (London), Ltd. The American paper is based on a Manual of Cost Finding Principles recently prepared by the American Hot Dip Galvanisers Association and hinges largely on the concept of the "kettle hour rate," while the British paper is based on drawing up standard cost schedules and applying them to particular jobs. The joint discussion contains valuable contributions from different countries, describing experience with various costing systems.

In Chapter VIII, "Heating the Bath," MR. A. CELLI, now of Kiekhaefer Aeromarine Motors Inc., U.S.A., describes an Italian furnace design, evolved to deal with low-output baths; it incorporates high-temperature combustion chambers set behind carborundum radiant baffles, and is suitable for firing by either natural gas or heavy oil. Chapter IX on "Dross Formation" contains a comprehensive paper by MR. S. A. HISCOCK, describing the results of research work undertaken by the British Non-Ferrous Metals Research Association on the sources and control of dross formation. All the reactions occurring during both "wet" and "dry" galvanising are analysed from the point of view of dross formation, and a method of calculation is explained by which the major source of dross in any process can be identified by the practical galvaniser, and the advantages or disadvantages of any change in technique assessed. The discussion contains detailed fundamental observations from America and Germany on the relative merits of different flux compositions, in the aqueous or molten states, and their effects on dross formation.

In Chapter X, MR. W. R. THOMPSON in his paper "The Inspection of Galvanised Structural Steelwork" deals with the quality of the coating, and visual and laboratory methods of its determination. A particularly valuable feature is the series of 19 plates, printed in five colours, which are designed to guide inspectors in their visual examinations of galvanised work and to illustrate the defects which may arise in the basic steel,

during galvanising itself, or during faulty fabrication or storage of the galvanised work. Chapter XI consists of the paper " After-Treatments for Galvanised Steel " by MR. W. L. HALL of General Galvanisers, Ltd., which surveys the available methods of protecting or decorating work after galvanising, and the pre-treatments needed on freshly galvanised surfaces.

The final Chapter on " Incentives and Productivity " also contains material not usually presented at strictly technical meetings. In a paper on incentive schemes, MR. CH. VAN. KEMPEN of Johan Vis & Co. N.V. Verzinkerij, describes the " A.B.C." incentive scheme, based on the Scanlon plan, which has been adopted in Holland with striking effects on galvanising productivity. MR. A. G. NORTHCOTT, of the Hot Dip Galvanisers Association, in his paper on the problems of productivity outlines the basic factors on which productivity depends. This chapter also concludes with a joint discussion, concerned with experience of incentive schemes in several European countries, and the wider applications of the principles of productivity within the galvanising industry.

Two hundred and thirty galvanisers and metallurgists with a special interest in the process from 14 different countries attended the Conference, and their opinions expressed during discussion form valuable additions to the text of each paper.

THE STRENGTH OF COPPER TUBES AND CYLINDERS

44 pp. Copper Development Association, Kendals Hall, Radlett, Herts. No charge.

ENGINEERS who are interested in copper tubes and cylinders will welcome this new C.D.A. booklet, which is intended to meet the demand for information on the effects of operating conditions and for guidance on design principles. It is hoped that a better understanding of the relevant properties of the metal will lead to more efficient and more widespread use of copper for pipe lines and cylinders. While some aspects of the subject matter covered may also be of interest to users of high-conductivity tubes, electrical requirements have not been taken into consideration.

The booklet is well illustrated, and includes a bibliography, a list of British Standards, and some alignment charts.

STATISTICAL SUMMARY OF THE MINERAL INDUSTRY, 1948–53

Prepared by Mineral Resources Division, Colonial Geological Surveys. 356 pp. London, 1955. H.M. Stationery Office. 27s. 6d. (by post 28s.).

THIS volume of statistical tables contains comprehensive details of production, exports and imports for all important commercial metals used throughout the world. The new edition covers the important six-year period 1948 to 1953.

Production tables for copper, lead, tin and zinc show not only the outputs of the relevant ores in terms of metal, but also give the figures of smelter production. In the case of aluminium, figures for bauxite and natural cryolite are also shown. The section on coal deals with coke, briquettes and the chief coal by-products; moreover, as the same unit of weight is used in the section on petroleum—which includes other natural products as well as the chief refinery products—comparison of the output and trade of these two principal fuels is readily available. Full available statistics are given for the minor metals—for example, lithium, columbium, tantalum and titanium—which are becoming of increasing importance in modern industry. In the export and import tables, not only are the crude minerals and metals recorded, but details are also given of the chief semi-manufactured products, refinery products and other derivatives.

The " Statistical Summary " is claimed to be the most complete reference book of its type, and its value to industrialists, economists, planners, mining engineers and others concerned with the metal and mineral industry is appreciated the world over.

Trade Publications

THE GENERAL ELECTRIC CO., LTD., have recently issued a publication dealing with the welding cables made by Pirelli-General Cable Works, Ltd. These include electrode holder cables which are designed to have maximum flexibility and are of normal and heavy types, the latter being suitable for situations where cables are exposed to extreme conditions, as in some shipbuilding work. Distributor cables for multiple arc A.C. welding plant are produced in two types (a 4-core, 300-amp type and a 7-core, 300-amp type: details of construction and operating characteristics are given.

G.W.B. FURNACES, LTD., are now manufacturing a range of arc furnaces developed by the Tagliaferri Company in Italy. This includes indirect arc rocking furnaces for iron and non-ferrous metals; direct arc fore-hearths for superheating and refining cupola melted irons; direct arc furnaces for the production of steels and high duty irons; submerged arc furnaces for the production of ferro-alloys and calcium carbide and the reduction of iron ore. A feature of the Tagliaferri design is the hydraulic control of electrodes, tilting mechanism, roof raising, etc., and three distinct types are available to cover a range of operating conditions. These include (1) fixed roof, rear-door charging type, which is mainly limited to small outputs of specialised steels and superheating of irons; (2) the lift and swing aside roof type; and (3) the bridge type in which charging is effected by withdrawing the furnace shell from beneath a gantry bridge carrying the electrode equipment.

IT is now more than 160 years since George Newton and Thomas Chambers joined as partners in an enterprise for the mining and processing of iron ore and coal. In time the smelting of iron ore, the local deposits of which had long been worked out, became uneconomic, and with nationalisation of the coal industry the firm also lost its coal mines and coke ovens. These changes, however, served to stimulate progress in chemical and engineering products in which the Company was also interested, and to-day the heavy construction department is an important unit of the Newton Chambers organisation. It is engaged in the design, fabrication, machining, assembly and site erection of equipment for the gas, iron and steel, chemical and oil industries. A new brochure issued by the Company illustrates effectively the wide range of heavy industrial equipment designed and manufactured at Thorncliffe. Of particular interest are the items of iron and steel works transportation equipment, including steel ladles and carriages, hot

metal ladles and cars, steel casting ladles, ingot casting cars and other cars, carriages and bogies used in the iron and steel industry. The department also undertakes construction and reconstruction of blast furnace plant and ancillary equipment, and the manufacture of fuel economy plant such as recuperators, economisers, air heaters and gas heaters. Other products include plant for the gas, chemical and oil industries.

LEIGH & SILLAVAN, LTD., of Arkwright House, Manchester, 3, have recently published a 32-page brochure detailing the companies on whose behalf they act as agents and distributors, and the types of products concerned. The latter range from pig iron to fabricated steel, and from aluminium alloys to gun metal castings. Apart from that for British Electrical Repairs, Ltd., most of the agencies concern ferrous and non-ferrous metals and materials used in their production and fabrication.

No less than five leaflets have been issued recently by G.W.B. Furnaces, Ltd., dealing with various types of continuous furnaces. The first covers the "pull-through" type, used for annealing, hardening, tempering and patenting strip or wire, where the product is guided through the furnace within ducts or tubes, or upon suitable rollers, to ensure that the charge is not scraped or otherwise damaged. The rotary hearth and vertical conveyor types of furnace are included in one leaflet because they both represent a considerable saving in floor space compared with other types with equivalent capacity. Perhaps the most versatile type of continuous furnace, using mesh belt conveyors, is described in yet a third leaflet. The remaining two publications deal, respectively, with walking beam furnaces—normally employed when the heat treatment of relatively heavy items is required on a continuous basis—and chain and slat conveyor furnaces.

Two new leaflets issued by Aluminium Union, Ltd., refer to the use of aluminium for grain silos and caravan building respectively. The storage in airtight silos of grain for milling is now practised in some countries, and experience has shown that if the moisture content of the grain is below 19%, it can be kept almost indefinitely. Lightweight trailer caravans are increasing in popularity, and in the second leaflet attention is drawn to the advantage of aluminium sheeting in their construction. Practical hints are given for the working of this material and for its subsequent painting.

THE circumstances of war brought about the cessation of publication of the *Wild-Barfield Heat-Treatment Journal*, which for some years previously circulated to metallurgists and others interested. Since the war, the Wild-Barfield Heat-Treaters' Diary has been introduced, and has proved very popular. The inclusion of technical articles, and of abstracts from technical journals, is obviously impracticable in such a publication, so the decision to re-issue the *Wild-Barfield Heat-Treatment Journal* was taken, and Vol. V, No. 34—the first of the new series—has recently been published.

OF two new booklets recently issued by Keith Blackman, Ltd., of Tottenham, London, N.17, No. 32 deals with the Tornado range of APA propeller type fans which are now being made in sizes from 18 in. to 48 in. diameters. Briefly, the outstanding features of this three-bladed fan are its high volumetric capacity, non-overloading characteristics, high operational efficiency, quietness in operation, and strength and rigidity. Publication No. G.1 is the first of a new series of quarto size catalogues dealing with the K.B. range of industrial gas equipment. Its title is "Air Blast Equipment," and it covers the Type 3 mixture controller, zero governor, air blast injectors and burners.

THE first issue of the *Evershed News* appeared in February, 1953, its policy being to publish short news items about Evershed instruments and personnel. This editorial policy has been changed, the aim now being to publish articles of more general interest to the electrical, instrument and instrumentation industries, and also to outline the latest developments in instruments and their manufacture. Outside contributions will be welcomed, particularly those describing new or interesting applications of Evershed products. The first issue in the new style has just appeared, and subsequent numbers will be published at two-monthly intervals. Copies will be sent to those interested in these fields on application to Evershed & Vignoles, Ltd., Chiswick, London, W.4.

WHETHER it's tobacco or paper, textiles or metal, which requires cutting, Sanderson Brothers & Newbould, Ltd., of Attercliffe Steelworks, Sheffield, 9, make a knife for the job. They are, in fact, one of the oldest and largest makers of machine knives, and a new leaflet illustrates some 28 different types, and details the purposes for which they are used.

RATHER than issue a mere catalogue listing the uses and merits of VIM leather packings, Edgar Vaughan & Co., Ltd., of Legge Street, Birmingham, 4, have produced for those interested a "Handbook on Leather Packings for Hydraulic and Pneumatic Mechanisms," which deals with many practical aspects of hydraulic engineering upon which relevant information has hitherto been rather scarce. The purpose of the book is to feature principles and illustrate the most common applications, as well as lay down rules which should be observed in order to assure success in the design of the packings.

IN the latest issue of *Wiggin Nickel Alloys*, No. 31, most of the articles are of metallurgical interest, but three are particularly so. The first features the pickling of precision steel tubing in batches up to 2 tons in weight, using Monel for pickling baskets, chains, etc. The welding of a super press Monel roller for use in modern high-speed paper-making machinery, is described in the second paper, some 700 lb. of welding rods being used for three 20 ft. seams in $2\frac{3}{4}$ in. thick material. Reference is made on page 203 to Brightray H, the new grade of nickel-chromium alloy for high temperature furnace resistors, whose properties are detailed in the third article.

Books Received

"Nickel in Iron and Steel." By A. M. Hall. (Alloys of Iron Research Monograph Series—Director and Editor: Frank T. Sisco). 595 pp. inc. name and subject indexes and numerous illustrations. New York and London, 1955. Published for The Engineering Foundation by John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 80s. net.

"Shell Molding and Shell Mold Castings," by T. C. Du Mond. 128 pp. inc. index. New York and London, 1954. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 16s. net.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
APRIL, 1955 Vol. LI, No. 306

The Use of Formvar for Mounting Metallographic Specimens

By J. V. Hardy, B.A., and A. D. Hopkins, M.Sc., A.I.M.
G.K.N. Group Research Laboratory

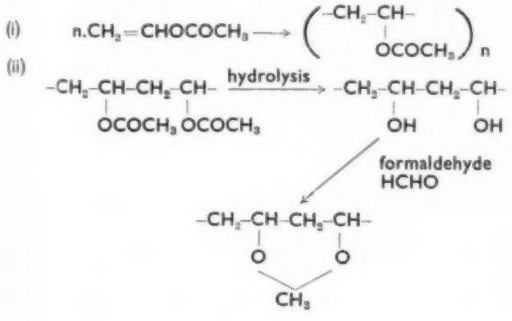
Microspecimens mounted in Formvar do not suffer from staining due to shrinkage of the mount from the specimen, nor are the edges rounded on polishing. A technique is described for carrying out the mounting operation using normal metallographic laboratory apparatus.

THE microscopic examination of coatings and scales usually presents difficulties; to avoid bevelling the edges of specimens and to prevent staining after etching is a difficult and time-consuming process. Since the usual mounting plastics are soft relative to metal specimens, it is, unfortunately, easy to bevel the specimens during polishing, with the result that, during microscopic examination, especially at high magnification, it is impossible to focus clearly on the edges. Staining often arises out of the tendency of mounting plastics to shrink from the specimen, leaving a minute gap which can retain the liquids employed during polishing and etching, later allowing them to seep out onto the surface. The authors have never obtained consistent results with any of the procedures usually recommended to remedy these defects, and until the present have found that patience and pertinacity are the main ingredients for success.

The method described below, involving the use of Formvar (polyvinyl formal) as a mounting medium, has been found to give uniformly successful results on a variety of specimens, and can be used without special skill or the need for apparatus beyond the scope of a normal metallographic laboratory.

Properties of Formvar

The preparation and properties of Formvar have been described in detail by Fitzhugh, Lavin and Morrison[1]. Briefly, it is made by polymerising vinyl acetate and then replacing the acetyl radicals of the side-chains of the polymer, firstly by hydroxyl groups, and secondly by formal groups.



The two steps of equation (ii) can be carried out simultaneously. The replacement reactions never proceed to completion, so that some hydroxyl and some acetyl groups remain on the chain. Several grades of Formvar are available : they are denoted by a fractional number in which the numerator represents a measure of the molecular weight of the original polyvinyl acetate, and the denominator represents the percentage extent to which the acetyl groups have been replaced by hydroxyl and formal groups—for example, Formvar 15/95. Physical properties alter with these variables, but, generally speaking, Formvar combines hardness and toughness, and is resistant to all the reagents normally encountered in metallographic work. Common solvents include acetic acid, trichloroethylene, and mixtures of polar and non-polar solvents, e.g., acetone with trichloroethylene. It is supplied in powder form, and its flow temperature is in the range 140–170° C. which, although rather high, does not prevent its use in an ordinary mounting press.

The hardness of a Formvar mount has been found beneficial in metallographic polishing, and its other useful property—that of "wetting" the specimen—causes it to penetrate and support minute irregularities, so preventing shrinkage and the resultant staining mentioned above. This latter property of Formvar is well illustrated by its use in the replica technique of electron microscopy[2], and in the stripping of surface films[3]. Formvar 15/95E has been found most suitable for metallographic mounting. The suffix "E" refers to its originally-intended use as an electrical insulator for wires. Formvar 15/95S is essentially the same material with the addition of a high-temperature stabiliser. Generally, it was found to be slightly inferior to the 15/95E grade in that it tended at times to pull away from the specimen, although to a lesser degree than Bakelite, for example. The effect of the stabiliser is to give a clear, transparent mount which may be advantageous on occasion, whereas the 15/95E grade gives a dark brown translucent mount.

Mounting Technique

The method developed for mounting specimens in Formvar is described below.

The die and plunger of a Millen mounting press are smeared sparingly with silicone grease, except for the

Fig. 1.—Thin layer of chromium plating on nickel-plated steel. ×1,000

face which bears the specimen. If this part is greased, the plastic will crumble and pit during polishing, as apparently the silicone grease prevents it from consolidating. After the specimen has been positioned, the mould is filled with powdered Formvar, the plunger inserted, and the powder compressed manually to compact it, as it has a low bulk-density. More powder is added to fill the mould and then heating is started in the normal way. The temperature should rise to 220° C. and a pressure of 3,000 lb./sq. in. should be employed. As the heating may be rather protracted with elements designed for use with Bakelite and Lucite, it may be found better in routine work to supplement the heating with a Bunsen burner. Pressure is maintained during cooling and the mount may be expelled from the die at 50° C. Thereafter, it is treated in the usual way. The use of silicone grease makes ejection much easier. Other greases are less suitable because of the relatively high temperature employed during mounting.

Powdered Formvar compresses in the cold to form a hard compact, and the above technique should be modified for thin sheets, otherwise the specimens may be pushed over or bent. For such specimens pressure should not be applied, beyond the small value necessary to close the mould, until the temperature has reached 170° C. by which time the Formvar has become plastic.

Polishing and etching present no special difficulties. Formvar is hard from abrasion-resistance considerations, but is readily cut away by emery papers, etc.; nevertheless, the composite surface, Formvar—metal specimen—Formvar, remains perfectly plane. The high quality of the preparation possible may be judged from the illustrations (Figs. 1 and 2) which show the edges of the specimens clearly and in perfect focus, even at high magnification. The absence of any gap between the plastic and the metal, and the freedom from stain at the edge is also noteworthy. One photomicrograph also illustrates the hardness of the material. Scratches, which are removed from the metal by polishing prepara-

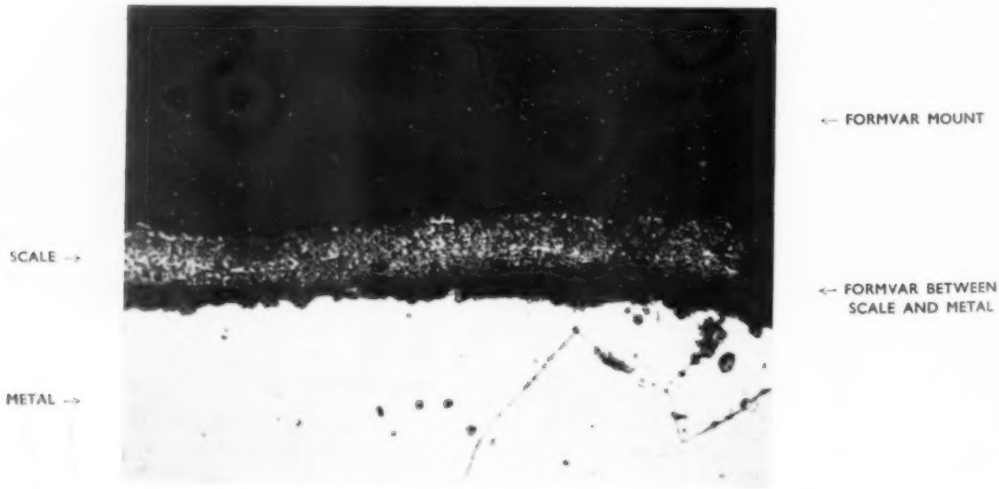


Fig. 2.—Silicon iron sample showing scale leaving the metal surface. Etched 10% nital. ×500

tions such as gamma alumina or B.C.I.R.A. polishing cream, are still visible in the plastic.

The following figures represent the cost per mount of the moulding materials used for three different methods :—

Bakelite	¼d.
N.H.P.[4]	7½d.
Formvar 15/95	8d.

To these costs must be added a small amount for heating. Assuming the cost of labour to be constant for each method, it becomes evident that at present the use of the newer moulding materials will be generally confined to those applications in which edge preservation is most important. Nevertheless, Formvar will be found invaluable where preparations of high quality are required.

Acknowledgment

The authors are indebted to Dr. T. Emmerson, Director of Research, G.K.N. Group Research Laboratory, Wolverhampton, for permission to publish this communication.

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The Polarographic Society

Papers Presented at Second Meeting

THE Second General Meeting of the Polarographic Society was held on Thursday, February 17, in the Lecture Theatre of the Pharmaceutical Society of Great Britain, 17, Bloomsbury Square, London, W.C.1, with Mr. W. J. Parker in the Chair. The Chairman referred to the first meeting, which had been reported in the first issue of the Society's Journal. The following papers were then read :—

The Use of the Polarograph in Fine Chemical Analysis

J. T. YARDLEY & A. G. MORRIS (*Hopkin & Williams, Ltd.*)

Reagent chemical analysis was ultimately concerned with the estimation of very small amounts of substance *A* in the presence of very large amounts of substance *B*, and this kind of analysis constituted the main application of the polarograph in the authors' laboratory. As the ratio *A* : *B* decreased, it became necessary to employ solutions of increasing concentration. This introduced a variety of problems concerning the major constituent, which might attack the electrode system, or be too insoluble to produce a measurable impurity wave. Quite apart from these difficulties, however, the resolution obtained was rather less than when estimating *A* (e.g., nickel) as a major constituent. Nevertheless, the fact that one could often polarograph an aqueous solution of the sample without any addition or other treatment constituted a practical simplicity rarely found in other techniques. With little effort, therefore, a rough qualitative and quantitative picture of the sample could be obtained. This was especially useful in exploring new sources of material. The matter of " blanks " was another great virtue of the technique, for the residual current curve provided a rapid and elegant method of checking the solvent and ancillary reagents. In the estimation of nickel impurities in cobalt salts, polarography was more convenient that absorptiometry, when large numbers of samples were dealt with. Furthermore, the polarograph was superior to the flame photometer in determining the alkali or alkaline earth metal content of certain organic samples. The polarograph had also been found useful in the following estimations : lead, copper and zinc in ferrous salts ; zinc in alkali cyanides and in high grade lead ; antimony ; lead (especially in the range 10–100 p.p.m.) ; and the stability of cuprous chloride. The technique also seemed promising in the determination of tellurium in selenium.

From Engineering to Polarography

C. L. WILSON (late of *Cambridge Instrument Co., Ltd.*).

In his first encounter with polarography, the author had met an unfortunate dichotomy, in that the chemist understood the chemistry and applications of the polarograph, but knew little of its instrumentation, whilst the physicist's knowledge lay in the opposite direction. Most chemical users of the polarograph were completely engrossed in their own problems and seemed to have no wish to impart their knowledge to engineers. This was unfortunate, for engineers could probably make great use of polarography in automatic process control and like problems. By virtue of its automatic recording facility, the average polarograph could often be included in a servo system with but little modification. As in most applications of electrochemical instrumentation to this kind of problem, the main difficulty lay in the electrode system. To illustrate his point of view, the author cited three possible engineering problems, which might be satisfactorily solved by polarography :—

(1) In certain plating baths, it was necessary to maintain a constant concentration of zinc by periodic additions of a concentrated solution of a zinc salt. These additions might well be controlled by means of a polarographically operated solenoid valve.
(2) The control of metals in industrial effluents required the sort of continuous indication, which the polarograph afforded.
(3) The corrosion of pipes might be detectable polarographically by analysis of soil samples taken from the vicinity of the pipe. A recent successful engineering application of the polarograph concerned the control of dissolved oxygen in boiler feed water.

The Polarography of Aromatic Nitro Compounds

DR. J. G. WALLER (*National Benzole Co., Ltd.*).

In the normal four-electron reduction of nitrobenzene, the first two stages appeared to be reversible and were followed by a third, probably irreversible, stage which

seemed to involve the loss of a molecule of water. In the last two stages, nitrosobenzene was reversibly reduced to phenyl hydroxylamine. At high and low *p*H values, the reduction of *o*- and *p*-nitrophenols required six electrons, whilst four electrons were required at *p*H 5. Brdicka had explained this in terms of an acid-base catalysed rearrangement of the *o*- and *p*-hydroxyphenylhydroxylamines to the corresponding quinone imines. A similar explanation was applied to the reduction of *o*- and *p*-dinitrobenzenes. In this case, a four-electron wave was followed by a second wave, which involved six electrons in neutral solution, but eight electrons at high or low *p*H values. Possible intermediates in the reduction of the dinitro compounds were the nitroanilines, which reduced in single six electron steps at all *p*H values; the rearrangement of nitrosoaniline appeared to be concerned. Both the amino and hydroxylamino substituents promoted the reduction of nitro to amino. Substitution of the nitroaniline amino group caused the nitro reduction to stop short at the hydroxylamino stage, as with nitrobenzene itself. The reduction of the nitrobenzoic acids and their methyl esters was also discussed.

Society of Non-Destructive Examination

THE rapid progress of the recently formed Society of Non-Destructive Examination has been not only marked by a steadily increasing membership but also characterised by extremely lively discussions at the technical meetings held so far. At the last quarterly meeting, Mr. K. B. Robinson, a director of the well-known shipbuilding company of Alexander Stephen & Sons, Ltd. gave an informal talk on the physical and economic aspects of non-destructive testing applied to shipbuilding. Apart from stressing the growing need for more non-destructive testing of welds in his industry, he emphasised the value of the human factor or "humanics". Vital problems included the supply of reliable personnel in supervisory grades; training; quality control of welding; and methods of payment. Much of the subsequent discussion centred on the present cost of radiography—estimates varied from 5s. to 30s. per foot—the vulnerability of X-ray equipment and limitation in the supply of radioactive isotopes for gamma-ray work. The next quarterly meeting of S.O.N.D.E. takes place on April 22nd when the guest speaker will be Mr. E. W. Colbeck, metallurgical and research director of Hadfields, Ltd., who will be talking on the application of non-destructive examination methods to heavy castings and forgings.

Although the headquarters of the Society is in London at Duncan House, Dolphin Square, S.W.1., its policy is to hold a number of meetings in various industrial centres, and, accordingly, the summer meeting will be held in Manchester on July 15th next. On this occasion members will listen to a contribution by Mr. L. E. Benson, chief metallurgist of Metropolitan-Vickers Electrical Co., Ltd. on non-destructive testing applied to electrical engineering production.

Metal Laboratory Furniture Merger

GRIFFIN AND GEORGE LTD. announce a further expansion of their laboratory equipment supply services. A new company, Grundy Equipment Ltd., has been formed in close association with Grundy (Teddington) Ltd., the well-known metal workers and engineers. This step, which has been taken to meet the growing demand for all-metal unit furniture and service pipework for laboratories, will add to the existing Griffin and George facilities, which already include the manufacture of furniture in wood.

It will be recalled that Griffin and George Ltd., was formed in June last year by amalgamating the resources of Griffin and Tatlock Ltd., W. and J. George and Becker Ltd., and Standley Belcher and Mason Ltd. Griffin and George will act as sole selling agents for the new company, which will concentrate on production in the Teddington works until arrangements have been completed for a new factory.

Working Model of Harwell Atomic Pile

THE United Kingdom Atomic Energy Authority has lent to the Science Museum, South Kensington, a large working model showing the B.E.P.O. pile, the larger of the two pioneer atomic piles set up at Harwell. This pile went into operation in July 1948 and is used for research purposes and for preparing radioactive isotopes for use in medical research and treatment, in agricultural research and in industry. The model goes through a complete cycle of operations in five minutes and shows the working of the control and shut-down rods which govern the heat output and activity of the pile, and the movement of the hoist for loading fresh uranium rods into the pile to replace those contaminated by fission products.

The model is on view in a recently opened ground floor gallery of the Museum. The Science Museum is open on weekdays from 10 a.m. to 6 p.m. and on Sundays from 2.30 to 6 p.m. (Closed on Good Friday and Christmas Day). Admission free.

Naresco Canadian Representative

MEASUREMENT ENGINEERING LTD. has been appointed Canadian sales representative by Naresco Equipment Corporation, equipment sales subsidiary of National Research Corporation. With headquarters in Arnprior, Ontario, and a branch at 226, Donlea Drive, Toronto 17, Ontario, Measurement Engineering will sell the entire line of high vacuum equipment manufactured by the Equipment Division of National Research Corporation, 160, Charlemont Street, Newton Highlands 61, Massachusetts. Featured in this line are high capacity mechanical and diffusion pumps, vacuum coaters, vacuum furnaces, and vacuum gauges, valves, and seals.

THE telephone number of J. B. Eaty & Co., Ltd., manufacturers of dial gauges, has been changed to Abbey (London) 7382 (five lines).

JAMES BOOTH & CO., LTD., have opened new sales offices in Newcastle and Glasgow. The former, under the managership of Mr. C. C. Barber, is situated at Exchange Buildings, Quayside, Newcastle upon Tyne, 1 (Tel.: 29731) Mr. C. G. Skidmore is the manager of the Glasgow branch at 93, Hope Street, Glasgow, C.2 (Tel.: Central 2715.)

THE Flame Radiation British Committee is now situated at 6, De Vere Gardens, London, W.8. (Tel.: Western 0761.)